44th Annual Congress of the

International Association of Hydrogeologists (IAH)

"Groundwater Heritage and Sustainability"

Dubrovnik, Croatia, September 25th to 29th 2017

Book of Abstracts

http://iah2017.org/

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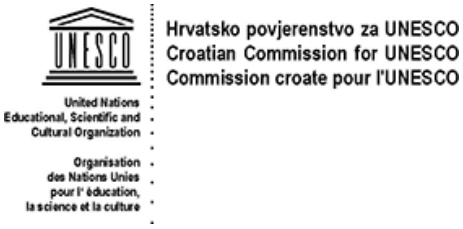

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Foreword

The Croatian National Chapter of the International Association of Hydrogeologists is honoured to host the 44th Annual Congress "Groundwater Heritage and Sustainability" in the Dubrovnik Palace hotel, Dubrovnik, Croatia, from 25th to 29th September 2017.

The city of Dubrovnik is the jewel of Croatian tourism, occupying a spectacular location on the eastern Adriatic coast. The city was declared a World Heritage Site by UNESCO in 1979.

The presence of the fresh water has been one of the key influences on the location of settlements throughout the history of mankind. The utilization of groundwater sources is therefore as old as human settlement and has become the part of our cultural heritage – a natural heritage which must be preserved. Due to significant industrial, agricultural, mining and touristic activities in the past century, together with the effects of climate change, the sustainability of groundwater use is now in the spotlight of hydrogeological research. Both the quality and quantity of groundwater sources are at risk of deterioration, and it is our task to reconcile meeting the water demands of contemporary settlements and economies with the need for conservation of this natural and cultural heritage in different environments around the globe.

The community of Croatian hydrogeologists would like to invite colleagues who deal with groundwater issues from different aspects to join this congress and share their ideas, experiences and knowledge. We extend our welcome to fellow scientists, engineers, other professionals, policy makers, government officials, as well as to students interested in groundwater.

Tamara Marković
President of the Croatian IAH Chapter

Topics and Sessions

T1. Groundwater Heritage – Passing Benefits to Current and Future Generations

Description: Groundwater heritage focuses on groundwater reserves as well as groundwater quality by passing benefits from past to current, and from current to future generations. Identification of declining or rising trends of groundwater levels i.e. groundwater reserves vital for human existence, as well as trends in groundwater quality deterioration or improvement in the past, present and future, give us a better insight into our groundwater heritage. Such knowledge is also of importance in planning and preserving current and the future quantitative and qualitative status of groundwater, the most important natural resource that makes up an estimated 98 to 99 percent of all freshwater in the world available for our use. What are the trends in groundwater levels i.e. reserves and quality? How are they affecting groundwater protection? What are the main sources of groundwater contamination? Moreover, how does climate change involving extreme conditions and events affect groundwater?

Sessions

T1.1. Groundwater heritage and trends in water levels, flows and quality

T1.2. Groundwater management and energy source development in a changing climate

T2. Sustainable Management of Groundwater Resources

Description: Sustainable management of groundwater resources is necessary to control the risks and pressures on groundwater caused by existing and increasing anthropogenic pressures, as well as present climate change and variations. This topic is mainly focused on developing countries, but experience and knowledge gained in sustainable management of groundwater resources worldwide is also relevant. Management strategies for sustainable use of groundwater resources differ according to variations in natural conditions and differing degrees of interaction with groundwater. What are appropriate response actions and emergency plans in a changing natural and socio-economic environment? What are adaptation measures for solving conflicts between competing sectors and their demands? What are the measures for sustainable groundwater recharge management? What is the importance of protecting transboundary aquifers? What are the planned actions for achieving the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development (adopted by world leaders in September 2015 at an UN Summit)?

Sessions

T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

T2.2. The role of groundwater in reducing poverty

T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

T2.4. Managed Aquifer Recharge

T2.5. Transdisciplinary and participatory approaches in groundwater research and management

T2.6. Regulatory framework of groundwater management

T2.7. Groundwater quality and natural environmental tracers

T2.8. Management of groundwater systems in urban and mining areas

T3. Groundwater Modelling

Description: Topic is focused on research of intergranular, karst and hard rock systems presenting various modelling approaches, both analytical and numerical, for solving groundwater flow and contaminant transport problems in groundwater resources management and protection. Flow and transport modelling in fully and variably saturated media, groundwater/surface water interactions, parameter estimation and uncertainty analysis, stochastic modelling.

Sessions

T3.1. Groundwater modelling in intergranular systems

T3.2. Groundwater modelling in fractured systems

T3.3. Using unconventional observation data in hydrogeological modelling

T3.4. Groundwater flow and transport modelling

T3.5. Groundwater modelling and management

T4. Groundwater Monitoring – New Approaches

Description: This topic focuses on standard and new approaches and technologies used in monitoring and characterization of quality and quantity status of groundwater, as well as in biological monitoring of underground aquatic ecosystems. Moreover, the topic extends to monitoring of all water balance components important for groundwater management and protection.

Sessions

T4.1. Monitoring of groundwater levels and flows

T4.2. Monitoring of groundwater quality and contamination

T4.3. Tracer experiments and application of natural isotopes in groundwater studies

T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

T4.5. Groundwater resources evaluation and management under arid conditions

T5. Groundwater in Karst Systems

Description: Specifics of groundwater flow in karst environment, bifurcations, trifurcations, accumulating groundwater in karst environments, impact of karst groundwater on rock characteristics, speleogenesis in karst hydrogeology, significant hydrogeological phenomena in Dinaric karst, significant hydrogeological phenomena worldwide.

Sessions

T5.1. Sustainability of karst aquifer use – global and regional outlooks

T5.2. Functionality and control of groundwater flow in karst

T5.3. Modelling of flow and contaminant transport in karst

T5.4. Protection of karst sources and environment

T5.5. Karst groundwater quality and contamination

T5.6. Novel methods and techniques for karst aquifer characterization

T6. Coastal and Island Hydrogeology

Description: Many areas worldwide have no better solution of their water supply than to use groundwater which is subjected to underground influence of seawater. In coastal zones such seawater penetration forms more or less regular wedge under fresh water; or freshwater forms a lens above seawater – usually in small island aquifers. Between fresh and salt water a wide transition or mixing zones is being formed, what makes this complex environment even more difficult for research and especially modelling. If there is no possibility to use completely fresh water in such zones, than brackish water extracted from transition (or mixing) zone can be used after certain desalination. Further, changes in climate and sea level drive changes of the coastal and island aquifers, which will in turn affect coastal and island ecosystems as well as human population. This topic comprises specific problems of groundwater in coastal and island areas, which are under influence of seawater penetration, as well as future climate and sea level changes. Modelling of such aquifers, their monitoring, hydrochemical and geophysical research, desalination, water management, water supply, assessment of potential impacts on the sustainability of coastal and island aquifers and habitats, as well as very specific coastal and island aquifers in karstic areas, will be main focuses of the topic.

Sessions

T6.1. Modelling of coastal and island aquifers

T6.2. Monitoring of seawater influenced aquifers

T6.3. Sea-aquifer relationship – using new and old tools

T6.4. Management of groundwater resources of coastal aquifers

T7. Groundwater and Dependent Ecosystems

Description: Groundwater and aquatic ecosystems are highly connected, whether we consider underground ecosystems or terrestrial groundwater dependent ecosystems. Consumption and irrigated agriculture are putting increasing pressures on groundwater quantity and quality, which can in turn have negative impacts on public water supply as well as on groundwater dependent ecosystems. How does groundwater interact with aquatic ecosystems? How does consumption and irrigated agriculture affect groundwater reserves? To what extent does this demand affect forest and wetland ecosystems?

Sessions

T7.1. Methods for characterisation of groundwater dependent ecosystems

T7.2. Groundwater and associated aquatic ecosystems

T7.3. Groundwater and terrestrial ecosystems

T8. Mineral and Geothermal Waters

Description: The practice of using mineral and geothermal waters for treatment and curing of diseases as well as heating has a long history. Geothermal energy is a renewable energy resource which produces less pollution than non-renewable resources. Nevertheless, they do have some environmental impacts. What is the interpretation of the term mineral waters in different countries? Exploration methods of origin of mineral and geothermal waters. What are the best approaches for ensuring sustainable use, protection and integrated environmental management of mineral and geothermal water sources? What are the benefits and environmental impacts of geothermal energy? What are best practises in mitigation of usage conflicts – bottling company vs. spa; transboundary water sources: country vs. country? What are the effects of mineral and geothermal waters on human health? What are the social and economic benefits?

Sessions

T8.1. Groundwater and Energy

T8.2. Geothermal reservoirs and their potential

T8.3. Hydrogeochemistry of thermal and mineral waters

Agenda

Monday, 25.9.2017

	MARE 1	MARE 2	MARE 3	MARE 4	DUBRAVA 1	DUBRAVA 2	LEVANT	KOKPIT
9:30-10:30	OPENING CEREMONY							
10:30-11:00	COFFEE BREAK IN HALL							
11:00-11:20	KEYNOTE BY ALICE AURELI (UNESCO)							
11:20-11:40	THEMATIC LECTURE - KARST MAP BY NICO GOLDSCHEIDER							
11:40-12:00	THEMATIC LECTURE - DIKTAS							
12:00-13:30	LUNCH IN HOTEL RESTAURANT							
13:30-14:00	KEYNOTE BY BOŽIDAR BIONDIĆ							
	T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE	T2.2. The role of groundwater in reducing poverty	T3.4. Groundwater flow and transport modelling	T4.3. Tracer experiments and application of natural isotopes in groundwater studies	T1.1. Groundwater heritage and trends in water levels, flows and quality	T5.2. Functionality and control of groundwater flow in karst		
14:00-14:15	T2.1.1 Brenčič Mihael: "Concept of regional groundwater flow as a tool in the delineation of groundwater bodies in accordance with the Water Framwork Directive"	T2.2.1 Tim Foster: "A multi-decadal financial assessment of groundwater services for low-income households in rural Kenya"	T3.4.1 Mariusz Czop: "Numerical modeling of the groundwater pollution and contaminant plume migration from the industrial waste site in Stalowa Wola (South Poland)"	T4.3.1 Thomas Vienken: "Chasing the tracer - combining conventional salt tracer testing with direct push electrical conductivity profiling for enhanced aquifer characterization"	T1.1.1 Bruce Misstear: "Groundwater heritage: the Holy wells of Ireland"	T5.2.1 Sasa Milanovic: "ANALYSIS OF DRAINAGE BOREHOLES FUNCTIONALITY ON PP GRANČAREVO ANCHOR FIELD"		
14:15-14:30	T2.1.2 Janos Szanyi: "Determination of minimum distance between production and injection wells in highly used porous geothermal reservoirs"	T2.2.2 Paul Pavelic: "Addressing seasonal flooding and groundwater depletion issues through innovations in MAR: Pilot tests and modelling to evaluate technical feasibility in the Ramganga basin, India"	T3.4.2 Daniele Pedretti: "Role of connectivity when modeling solute transport nearby pumping wells in heterogeneous media"	T4.3.2 Kent Novakowski: "Comparison of Characterization Methods Used to Develop Conceptual Models for Discrete Fracture Networks"	T1.1.2 Julian Conrad: "The springs of the City of Cape Town: Heritage and proposed spring use strategy"	T5.2.2 Jahanbakhsh Daneshian: "Application of sequence stratigraphic surfaces in karst hydrogeology: a case study from the Lar Formation, Central Alborz, Iran"		
14:30-14:45	T2.1.3 Anna J, Żurek: "Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea"	T2.2.3 Sospeter Wekesa: "Analyzing the groundwater potential and spatiotemporal interactions with surface water in the Sand River, Mara Basin, Kenya"	T3.4.3 Diego Di Curzio: "Reactive transport modeling for the evaluation of field scale substrate competition in a complex contaminated site"	T4.3.3 Jaeyeon Kim: "Monitoring groundwater-surface water interactions through radon tracer and microbial diversity around ground water heat pump system"	T1.1.3 Neno Kukuric: "The Value of Groundwater and Groundwater Heritage"	T5.2.3 Nadine Goeppert: "Compendium of more than 140 years of hydrogeological research at the Danube-Aach System, Germany"		
14:45-15:00	T2.1.4 Branka Bracic Zeleznik: "The Groundwater Level Trends - the Human impacts vs. Climate Change"	T2.2.4 Fabio Fussi: "Characterization of shallow aquifers in Guinea Bissau to support the promotion of manual drilling at country level"	T3.4.4 Ewa Kret: "Specifics of contaminant plume migration from the tailing pond within multilayer Quaternary aquifer with important influence of the river hyporheic zone"	T4.3.4 István Fórizs: "Relationship between the isotopic characteristics of local precipitation and groundwater"	T1.1.4 Ahmed Fekri: "An over exploited alluvial shallow aquifer in arid climate : threat and perspectives. Case of Feija (Morocco)"	T5.2.4 Mihael Brenčič: "Extreme and record discharges of Ljubljanica karstic spring system (Slovenia)"		
15:00-15:15	T2.1.5 Arianna Musacchio: "Socio-hydrogeological assessment of nitrate contamination in areas of intensive agricultural use: the case of the Lombardy Plain (North Italy)"	T2.2.5 David Walker: "Comparison of multiple groundwater recharge assessment methods for a shallow aquifer: Why are the results so varied?"		T4.3.5 Katarina David: "Geochemical methods for characterisation of organic material and groundwater in upland peat swamps"		T5.2.5 Anita Erőss: "Hydrogeological controls on hypogenic cave formation – case study from Budapest (Hungary)"		
15:15-15:30		T2.2.6 Adrian Healy: "Exploiting our groundwater resource: choices and challenges in managing the water commons"						
15:30-16:00	COFFEE BREAK IN HALL							
	T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE	T2.2. The role of groundwater in reducing poverty	T3.4. Groundwater flow and transport modelling	T4.1. Monitoring of groundwater levels and flows	T1.1. Groundwater heritage and trends in water levels, flows and quality	T5.2. Functionality and control of groundwater flow in karst		
16:00-16:15	T2.1.6 Brenčič Mihael: "Drinking water protection zones in Adriatic and Ionian region"	T2.2.7 Georg J. Houben: "Groundwater resources for the arid North of Namibia from an inland mega-fan system"	T3.4.5 Martina aus der Beek: "Applying modelling results to a modified query: The regression of chloride on modelled TDS"	T4.1.1 Sébastien Kech: "Assessing the potential groundwater withdrawals from water wells : a simplified method"	T1.1.5 Koki Kashiwaya: "Cause for spatial variation in tritium concentrations of groundwater in the southern coastal region of Fukushima, Japan"	T5.2.6 Natasa Ravbar: "Identifying flow dynamics and solute transport in a high karst plateau using tracer tests – a case study of the Javorniki – Snežnik karst massif (Slovenia)"		
16:15-16:30	T2.1.7 Ranko Biondić: "Groundwater status assessment of the Dinaric karst area of Croatia"	T2.2.8 Viviana Re: "Integrated socio-hydrogeological approach to tackle nitrate contamination in groundwater resources. The case of Grombalia Basin (Tunisia)"	T3.4.6 Luca Alberti: "Statistical methods and stochastic modeling to assess groundwater PCE diffuse pollution in Milan Functional Urban Area"	T4.1.2 Matthys Dippenaar: "Contributions to the Characterisation of the Vadose Zone for Hydrogeological Applications"	T1.1.6 Stefania Stevenazzi: "Influence of air pollution on rainfall chemistry and impacts on groundwater quality in the Milan urban area, Italy"	T5.2.7 Francesco Fiorillo: "Main hydraulic features of the upwelling water flux feeding karst springs"		
16:30-16:45	T2.1.8 Barbara Karleuša: "Sustainable Management of Groundwater Resources in the Context of Climate Change Impact Assessment - Examples from Croatian Karst areas"	T2.2.9 Richard Taylor: "Large-scale modelling of groundwater resources: insight from the comparison of models and in-situ observations in Sub-Saharan Africa"	T3.4.7 Changli Liu: "Experimental and numerical study of pollutant migration process in an aquifer in relation to Shaziying garbage dump field"	T4.1.3 Yung-Chia Chiu: "The Use of Thermograph and Hydrograph to Estimate Water Fluxes Across the Streambed at the Tributary of Chichiawan Creek, Taiwan"	T1.1.7 Chisato Yamada: "Mechanisms of groundwater level changes after the 2016 Kumamoto earthquake"	T5.2.8 John Sharp: "RECHARGE TO THE KARSTIC EDWARDS AQUIFER"		
16:45-17:00						T5.2.9 Giorgia Lucianetti: "Use of artificial and natural tracers to identify groundwater flow components in a high-alpine karst system (Dolomites, Italy)"		
17:00-19:00	POSTER SESSIONS IN HALL T1, T3, T8							
					National Chapters meeting from 17:45 til 18:45	Commission on Managing Aquifer Recharge		Burdon Groundwater Network for International Development
20:00	ECHN EVENT IN HOTEL'S DISCO							

Tuesday, 26.9.2017

	MARE 1	MARE 2	MARE 3	MARE 4	DUBRAVA 1	DUBRAVA 2	LEVANT	KOKPIT
8:30-9:00	KEYNOTE BY BARBARA ČENČUR CURK							
9:00-9:15	THEMATIC LECTURE - KINDRA BY MARCO PETITTA							
	T2.3. Sustainable management of groundwater resources worldwide – what have we learned?	T2.4. Managed Aquifer Recharge	T3.1. Groundwater modelling in intergranular systems	T3.5. Groundwater modelling and management	T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring	T5.1. Sustainability of karst aquifer use – global and regional outlooks		
9:15-9:30	T2.3.1 Rowena Hay: "Dealing with consequences of haphazard urban development across a coastal lowland: Hydrogeological importance of the Cape Flats Aquifer system, South Africa"	T2.4.1 Yogita Dashora: "Economics of recharge augmentation by four check dams on ephemeral streams in a hard rock area of Rajasthan, India"	T3.1.1 Jolanta Kazmierczak: "Arsenic contamination of the Quaternary aquifers of the Red River delta, Vietnam controlled by the hydrogeological processes"	T3.5.1 Wendy Timms: "Groundwater processes in geomechanical models of underground mining"	T4.4.1 Bessière Hélène: ""MétéEau des nappes": a decision making tool to characterize in almost real-time groundwater quantitative state"	T5.1.1 Zoran Stevanović: "Karst aquifer as one of the major global water sources - state of art and perspectives"		
9:30-9:45	T2.3.2 Ian White: "Groundwater security and sustainable development: the dilemma in atoll countries"	T2.4.2 Raul Nogueras: "ARTIFICIAL GROUNDWATER RECHARGE USING DEEP WELLS: EXPERIENCES AT MADRID TERTIARY DETRITAL AQUIFER"	T3.1.2 Anna Jaros: "The effect of a fully-integrated model parametrization on groundwater-surface interactions in boreal esker-mire landscape: example of the Olvassuo aapa mire in Finland"	T3.5.2 Elena Filimonova: "Groundwater resources dynamics in small-scale river basin under climate change conditions"	T4.4.2 Stefanie Bus: "Characterizing groundwater heads with online interactive time series analyses"	T5.1.2 Robert DiFilippo: "Development of a Freshwater Lens Assessment Protocol for Karst islands"		
9:45-10:00	T2.3.3 Núria Ferrer: "How do new development activities affect coastal groundwater systems in Africa? The case of Kwale, Kenya"	T2.4.3 José Pablo Bonilla Valverde: "Estimation of the screen length effect on injection wells"	T3.1.3 Majid Taie Semiromi: "A fully coupled SWAT-MODFLOW Model to simulate Surface-Groundwater Interactions: Application to the Gharehsoo River Basin, Iran"	T3.5.3 Kristijan Posavec: "Multipurpose project Programme Sava – numerical modeling of impact of Option 2A conceptual solution on groundwater"	T4.4.3 Albert Folch: "Combining different techniques to monitor seawater intrusion integrating different observation scales"	T5.1.3 Coran Kelly: "Establishing Geoscientific Zones of Contribution to Karst Drinking Supply Springs"		
10:00-10:15	T2.3.4 HANICH Lahoucine: "Sustainable management of surface and groundwater resources of the Tensift basin (Morocco)"	T2.4.4 Michaela Rückl: "Mapping aquifer productivity in the Sahel region: Harmonization of transboundary maps"	T3.1.4 Claire Carlier: "Catchment controls on storage and low-flow dynamics: a hydrogeological modelling approach."	T3.5.4 Ralf Junghanns: "MOFLOW-based web modeling framework"	T4.4.4 Carlos Maldaner: "Measuring changes in groundwater flow using fibre optic active distributed temperature sensing in bedrock boreholes"	T5.1.4 Matej Blatnik: "Ground water characteristics of the Ljubljanica River recharge area, Slovenia"		
10:15-10:30		T2.4.5 Frank Herrmann: "Links between the presence of snowpacks and groundwater recharge – Simulation results for the territory of Slovenia"	T3.1.5 Janja Vrzel: "Hydrodynamic and geochemical analysis of groundwater-surface water interactions (Ljubljansko polje, Slovenia)"	T3.5.5 Giovanna De Filippis: "Using advanced modeling tools for sound groundwater governance of transboundary aquifers in southern Africa: the Stampriet Transboundary Aquifer System case study"	T4.4.5 Ted McCormack: "Monitoring and Mapping Groundwater Flooding In Ireland"	T5.1.5 MEHMET EKMEKCI: "Hydrogeological conceptualisation of Pinarbasi karst spring for an effective protection zone delineation"		
10:30-10:45		T2.4.6 Yvan Caballero: "Mapping groundwater recharge with associated uncertainty at the regional scale"		T3.5.6 Joel Podgorski: "Water quality prediction mapping with the Groundwater Assessment Platform (GAP)"	T4.4.6 Mohammad Shamsudduha: "Recent changes in terrestrial water storage in the Upper Nile Basin: an evaluation of commonly used gridded GRACE products"	T5.1.6 Julian Xanke: "Managed aquifer recharge into a karst groundwater system at the Wala reservoir, Jordan"		
10:45-11:00		T2.4.7 Helen Seyler: "Promoting the Capture Principle Approach to Sustainable Groundwater Use in South Africa"		T3.5.7 Catalin Stefan: "A multi-scale perspective for the modelling of managed aquifer recharge (MAR) applications"	T4.4.7 Adi Tal: "Implementing of geophysical methods to monitor seawater intrusion in multi-layered coastal aquifer"	T5.1.7 Junbing Pu: "Critical Zone in China's karst area: a hydrogeological Perspective"		
11:00-11:30	COFFEE BREAK IN HALL							
	T2.3. Sustainable management of groundwater resources worldwide – what have we learned?	T2.4. Managed Aquifer Recharge	T3.1. Groundwater modelling in intergranular systems	T3.5. Groundwater modelling and management	T6.2. Monitoring of seawater influenced aquifers	T5.3. Modelling of flow and contaminant transport in karst		
11:30-11:45	T2.3.5 Geary Schindel: "Source Water Protection Strategies for Karst Aquifers"	T2.4.8 Andrew Ross: "The costs of managed aquifer recharge"	T3.1.6 Kosta Urumović: "Relations between mineralogical compound and hydrogeological properties of typical fine grained sediments in eastern Croatia"	T3.5.8 Luis Ribeiro: "Description of spatial variability of nitrate in Campina de Faro aquifer, Portugal by a non-linear geostatistical methodology"	T6.2.1 Zelimir Pekas: "Novljanska Žrnovnica spring – Specifics of groundwater discharge and abstraction regime"	T5.3.1 Lea Duran: "Comparison of pipe network and hybrid numerical models applied to karst systems in Ireland"		EARLY CAREER HYDROGEOLOGIST NETWORK (ECHN) SESSION - SUCCESSFUL PROJECTS: FROM APPLICATION TO MANAGEMENT - TIPS FROM SENIOR'S HYDROGEOLOGIST IN THE GOVERNMENT, INDUSTRY AND ACADEMIA TO EARLY CAREER HYDROGEOLOGISTS
11:45-12:00	T2.3.6 Arnauld Malard: "Visual KARSYS – a web-tool for the documentation of karst aquifers"	T2.4.9 Cao Wengeng: "Evaluation of Managed Aquifer Recharge Site Suitability for the North China Plain"	T3.1.7 Michela Trabucchi: "Recovery test interpretation under non-ideal conditions"	T3.5.9 Hasan Yazicigil: "Dewatering Design for an Open Pit Coal Mine and Assessment of Anticipated Impacts on the Groundwater Resources"	T6.2.2 Andres Gonzales Amaya: "Groundwater characterization in the semi-arid Punata alluvial fan (Bolivia"	T5.3.2 Laurence Gill: "Damped tidal signal at an inland ephemeral lake (turlough) used to infer karst conduit connection"		
12:00-12:15	T2.3.7 Laurence Bentley: "Towards Sustainable Groundwater Management in the Valle Alto de Cochabamba, Bolivia"	T2.4.10 Xin He: "Potential of using Managed Aquifer Recharge to restore groundwater aquifers in North China Plain"	T3.1.8 Nico Dalla Libera: "Subsoil geostatistical modeling as tool for hydrogeological modeling: Transitional Probability approach applied upon a heterogeneous site"	T3.5.10 Carlos Guevara Morel: "Effects of well ageing on the hydraulics of water wells"	T6.2.3 Giuseppe Sappa: "The state of art on the coastal aquifers database coming from the CAD-CZM network of IAH"	T5.3.3 Zhao Chen: "Modeling water fluxes and storages in an Alpine karst catchment in the context of climate change"		
12:15-12:30	T2.3.8 Sarah Shalsi: "Collective action in groundwater management – Lessons learnt from the Angas-Bremer irrigation district, South Australia"	T2.4.11 Jinchao Li: "Simulation of Managed Aquifer Recharge through Infiltration via Yufu River Channel Bed in Jinan"	T3.1.9 Berenice Zapata-Norberto: "Nonlinear consolidation in randomly heterogeneous highly compressible aquitards"	T3.5.11 Alexander Vandenbohede: "Groundwater flow and time series models: complementary techniques to derive groundwater dynamics."	T6.2.4 Tobias Holt: "Tidal-driven dynamics and evolution of a young freshwater lens on a juvenile barrier island, 'Ostplate', Spiekeroog"	T5.3.4 Andreas Hartmann: "On the value of water quality observations for karst model parameterization"		
12:30-12:45				T3.5.12 Russell Martin: "Groundwater modelling to facilitate regulatory change to realise operational efficiency at the Aldinga Managed Aquifer Recharge System "	T6.2.5 Marek Marciniak: "Direct measurements of submarine seepage of groundwater into the Puck Bay, Poland"	T5.3.5 Jean-Baptiste Charlier: "Quantifying surface water-groundwater interactions in a karst basin using the diffusive wave model"		
12:45-13:00				T3.5.13 Karlis Kukemilks: "Hydrogeological triggers of the Deisermillen landslide in the Mosel River valley, Luxembourg"	T6.2.6 Nele Grünenbaum: "Recirculation rates within beach sediments under meso-tidal conditions (Spiekeroog, Northern Germany)"	T5.3.6 Matías Mudarra: "Role-assessment of the soil-epikarst-unsaturated zone in the hydrogeological functioning of karst aquifers using a process-based simulation model"		
13:00-14:00	LUNCH IN HOTEL RESTAURANT							
14:00-14:30	KEYNOTE BY ANKER LAJER HØJBERG							
14:30-14:45	THEMATIC LECTURE - BIRDSALL-DREISS LECTURE BY EDWIN HARVEY							
	T2.8. Management of groundwater systems in urban and mining areas	T2.2. The role of groundwater in reducing poverty	T1.2. Groundwater management and energy source development in a changing climate	T3.5. Groundwater modelling and management	T4.5. Groundwater resources evaluation and management under arid conditions	T5.4. Protection of karst sources and environment		
14:45-15:00	T2.8.1 Sean Burke: "Impacts of Unconventional Gas Exploration on Groundwater"	T2.2.10 Michael Rivett: "On the rise of pit latrines and the safeguard of groundwater in Southern Malawi"	T1.2.1 Eric Morales-Casique: "Numerical groundwater flow and geochemical modeling for basin-scale hydrogeologic analysis"	T3.5.14 Nicolas Roux: "Long term groundwater level reanalysis over France using the multimodel parallel plateforme Aqui-FR"	T4.5.1 Roi Ram: "81Kr Dating of ancient 14C-depleted water: an example from the Nubian Sandstone Aquifer of the Negev Desert (Israel)"	T5.4.1 Branislav Petrović: "EPIK Intrinsic Groundwater Vulnerability Assessment and Statistical Sensitivity Analysis: Case Studies from Serbian Karst"		
15:00-15:15	T2.8.2 Patrick Morrissey: "Integrating Hydrus and Modflow to predict on-site wastewater trestment contaminant transport in different aquifers"	T2.2.11 Jade Ward: "Rapid screening for pathogens in drinking water: preliminary results from a national scale survey in Malawi"	T1.2.2 Gabriele Oberto: "Assessing the impact of climate change on groundwater resources using a coupled irrigation system/groundwater numerical model: a case study in Lodi province (Italy)"	T3.5.15 Aybulat Fatkhutdinov: "Multi-objective optimization of aquifer storage transfer and recovery systems based on evolutionary algorithm"	T4.5.2 Matthieu Baïsset: "Azraq aquifer overexploitation lead to a global salinization: the use of borehole geophysical monitoring tools to enhance groundwater management (Jordan)"	T5.4.2 Hrvoje Meaški: "Karst Aquifer Vulnerabilty Assesment (KAVA) method on the example of two catchments in Croatia"		
15:15-15:30	T2.8.3 Peter Somerville: "Regulating water extraction and salinity in an alluvial groundwater system in a heavily modified, coal-bearing, coastal catchment with sparse data"	T2.2.12 Richard Carter: "Groundwater access and poverty in sub-Sharan Africa: findings of a scoping study"	T1.2.3 Arnaud Sterckx: "The Impact of the Last Glaciation on Groundwater Flow in the northern Baltic Artesian Basin (BAB): A Numerical Study."	T3.5.16 Jana Glass: "Web-based compilation of empirical and analytical equations for the sustainable management of groundwater resources"	T4.5.3 Rainier Dennis: "Groundwater Resource Directed Measures"	T5.4.3 Pierre-Yann DAVID: "Middle Risle critical zone observatory : monitoring karstic processes evolution in the river, their impacts on surface water/groundwater interaction and their consequences on aquatic ecosystems"		
15:30-15:45		T2.2.13 Alan MacDonald: "Hand pump functionality: are the rural poor getting a raw deal ?"		T3.5.17 Stefan Broda: "Weekly, monthly and seasonal forecasting of groundwater levels using artificial neural networks"		T5.4.4 Husam Baalousha: "Vulnerability Mapping of Karst Aquifers in Qatar"		
15:45-16:15	COFFEE BREAK IN HALL							
	T2.8. Management of groundwater systems in urban and mining areas					T5.6. Novel methods and techniques for karst aquifer characterization		
16:15-16:30	T2.8.4 I. Gev: "Preservation of Groundwater Production Potential in Israel"					T5.6.1 Robert Agnew: "Classification of Free Phase Gas in Springs"		
16:30-16:45	T2.8.5 Ingelöv Eriksson: "Subsidence management in Oslo - from GIS analysis to urban planning"					T5.6.2 Simon Frank: "Fluorescence-based multi-parameter approach to examine the water quality of alpine karst springs"		
16:45-17:00	T2.8.6 Helen Seyler: "Water Sensitive Design Scenario Planning for Cape Town using an Urban (Geo)Hydrology Model"					T5.6.3 Jake Longenecker: "Karst spring catchment delineation using correlation between of hydrographs and satellite global precipitation measurements"		
17:00-19:00	POSTER SESSIONS IN HALL T5, T6							
			IAH Commission on Groundwater and Climate Change	ECHN Annual General Meeting	Commission on Karst Hydrogeology	Coastal Aquifers Management and Coastal Zone Dynamics Network	Commission on Mineral and Thermal Waters	Urban Groundwater Network
19:00	GENERAL ASSEMBLY							

Thursday, 28.9.2017

	MARE 1	MARE 2	MARE 3	MARE 4	DUBRAVA 1	DUBRAVA 2	LEVANT	KOKPIT
8:30-9:00	KEYNOTE BY NEVEN KREŠIĆ							
9:00-9:15	THEMATIC LECTURE - DARLINGE BY ANNAMARIA NADOR							
	T2.5. Transdisciplinary and participatory approaches in groundwater research and management	T2.7. Groundwater quality and natural environmental tracers	T3.2. Groundwater modelling in fractured systems	T7.2.Groundwater and associated aquatic ecosystems	T4.2. Monitoring of groundwater quality and contamination	T5.5. Karst groundwater quality and contamination		
9:15-9:30	T2.5.1 Emily Hepburn: "A method for separation of metal sources in groundwater using high-resolution XRF, geochemical and hydrogeological indicators: Fishermans Bend, Australia"	T2.7.1 Jared van Rooyen: "Groundwater tritium anomalies in South Africa and their bearing on groundwater recharge estimates"	T3.2.1 Luka Malenica: "Hybrid meshless karst flow model using the finite volume approach"	T7.2.1 Ádám Tóth: "Comprehensive hydrogeological study to reveal groundwater-dependency of the largest lacustrine ecosystem in Central Europe"	T4.2.1 Andras Jakab: "A Holistic Approach to Groundwater Management"	T5.5.1 Nico Goldscheider: "Urban impacts on the groundwater quality and quantity of a karst aquifer in Jordan"		
9:30-9:45	T2.5.2 Elia Cantoni: "A sensitivity analysis of the impacts of climate change on groundwater recharge in low storativity fractured-bedrock aquifers in Ireland"	T2.7.2 Dong-Chan Koh: "Hydrogeochemical and isotopic characterization of bedrock groundwater in a mountinous area during pumping tests"	T3.2.2 Jean-Christophe Maréchal: "Water inflows into a deep tunnel through the Reunion volcano: observation and modeling"	T7.2.2 Marciniak Marek: "Field measurements of the direction and magnitude of groundwater and surface water exchange in the hyporheic zone"	T4.2.2 Jozef Kordik: "Assessment of contaminated sites in Slovakia – lessons learned from groundwater and surface water monitoring during 2014-2016"	T5.5.2 Petra Bodor: "Evolution of bacterial biofilms and chemical precipitates in thermal springs depending on flow kinetics (Buda Thermal Karst, Hungary)"		
9:45-10:00	T2.5.3 Marie-Louise Vogt: "Combining hydrochemistry and remote sensing for a better understanding of groundwater fluxes in Northern Chad"	T2.7.3 Hyun-Kwon Do: "Cause and implication of hydrochemical stratification of CO2-rich groundwater in a shallow monitoring well, South Korea"	T3.2.3 Carlos Ordens: "A conjunctive application of unsaturated zone modelling and field-based methods to assess recharge processes and quantify recharge rates in a coastal, semi-arid, karstic aquifer: Uley South Basin, South Australia"	T7.2.3 Antoine Biehler: "Biogeochemical connectivity in aquifer-river continuum – use of in situ 222Rn and PCO2 measurements in the study of CO2 outgassing induced by groundwater discharges in river"	T4.2.3 Kerry T.B. MacQuarrie: "Baseline groundwater status in private water wells in regions of potential shale gas development (New Brunswick, Canada)"	T5.5.3 Tianming Huang: "Hydrogeochemistry of a karst aquifer affected by acid rain in SW China"		
10:00-10:15	T2.5.4 Aleksandra Kiecak: "Comprehensive study of fate and transport of pharmaceuticals in groundwater (PERSIST Project)"	T2.7.4 Marco Petitta: "Isotopic characterization of groundwater tapped for drinking use in multilayer alluvial aquifers of Milano and Monza provinces, Italy"	T3.2.4 Owen Naughton: "A hydrological model for predicting flooding in geographically-isolated karst wetlands"	T7.2.4 Janet Herman: "Groundwater-stream connectivity and the fate of agricultural nutrients in coastal watersheds"	T4.2.4 Akinobu Miyakoshi: "Evaluation of groundwater environment changes due to urbanization in the Tokyo metropolitan area, Japan: Application of long-term monitoring of subsurface temperature and groundwater levels"	T5.5.4 Kern Lee: "The Role of Groundwater for Dissolved and Particulate Carbon Fluxes in a Small Karstic Stream: The Schwabach River, Bavaria, Germany"		
10:15-10:30	T2.5.5 Maria Luisa Calvache: "Estimation of the hydraulic conductivity from single dilution tests in the Motril-Salobreña detrital aquifer (SE Spain)"	T2.7.6 Juliana Ossa: "Physical, chemical and biological characterization as support for water governance in a hydrogeological system of Colombia"	T3.2.5 Laurence Gill: "Groundwater flooding in a lowland karst network in response to extreme rainfall and tidal event synchronicity"	T7.2.5 David O'Connell: "Hydro-chemical and geophysical techniques investigating dynamics and sources of DIC within a catchment possessing a Groundwater Fed Lake (Lough Gur, Ireland)"	T4.2.5 Natalia Vinograd: "Groundwater quality and contamination in the central part of the Oredezh river valley (St.Petersburg Region, Russia)"	T5.5.5 Michael Sinreich: "Tracking fecal contamination in karst groundwater"		
10:30-10:45	T2.5.6 Roland Bäumle: "Exploring and managing deep-seated groundwater reserves in the Northern Kalahari Basin, Namibia"	T2.7.7 Dan Lapworth: "Security of groundwater abstraction in the deep coastal Bengal Aquifer System revealed by environmental tracers"	T3.2.6 Pierre-Yves Jeannin: "KMC: "Karst Modelling Challenge", a comparison between modelling approaches in karst"	T7.2.6 Jodie Miller: "Identifying and modelling sustainable groundwater inflows into the Verlorenvlei coastal estuarine system in South Africa"	T4.2.6 Gary Robbins: "Influences on Water Quality Samples from Open Borehole Wells in Fractured Crystalline Bedrock"	T5.5.6 Joanna Doummar: "Artificial sweeteners: Sucralose and Acesulfame; emerging pollutants indicators of specific transport in karst systems: Application to semi-arid regions."		
10:45-11:00	T2.5.7 Norhan Abd Rahman: "Investigation of Vibration Effect on Double-Porosity Soil for Non-Aqueous Phase Liquid Migration"	T2.7.5 Aleksandra Kiecak: "Laboratory study on sorption and biodegradation of selected pharmaceuticals – influence of flow velocity on transport"	T3.2.7 Stephen Worthington: "Geological considerations in modelling bedrock aquifers"		T4.2.7 Dominika Dabrowska: "Lysimeter research under simulated municipal landfill conditions"			
11:00-11:30	COFFEE BREAK IN HALL							
	T2.5. Transdisciplinary and participatory approaches in groundwater research and management	T2.7. Groundwater quality and natural environmental tracers	T3.2. Groundwater modelling in fractured systems	T7.3. Groundwater and terrestrial ecosystems	T4.2. Monitoring of groundwater quality and contamination	T6.1. Modelling of coastal and island aquifers		
11:30-11:45	T2.5.8 Ezra Haaf: "Investigating groundwater drought and dominant environmental controls with a focus on the drought of 2016 in Sweden"	T2.7.8 Dr. Manussawee Hengsuwan: "Strontium Isotopes as Natural Tracers in the Aquifer Storage and Recovery, Thailand"	T3.2.8 Rodrigo Lilla Manzione: "Spatio-temporal interpolation of water table depths in a conservation area at Bauru Aquifer System (SP/Brazil)"	T7.3.1 Bjørn Kløve: "Groundwater-surface water interaction in peatlands: modes of interaction at different scales"	T4.2.8 Igor Slaninka: "Monitoring of chlorinated hydrocarbons found in groundwater at selected contaminated sites in Slovakia"	T6.1.1 Katsushi Shirahata: "Heterogeneous hydraulic properties of an insular aquifer clarified by a tidal response method with simple decomposition techniques"		
11:45-12:00	T2.5.9 Loke Kok Foong: "Study of Aqueous and Non-Aqueous Phase Liquid in Double-Porosity Soil Using Digital Image Analysis"	T2.7.9 Janie Masse-Dufresne: "Studying dynamics of a bank filtration site via a multi-tracer approach"	T3.2.9 David Macdonald: "Improved understanding of spatio-temporal controls on regional scale groundwater flooding using hydrograph analysis and impulse response functions"	T7.3.2 Shane Regan: "Long-term impacts and controls of peripheral drainage on the ecohydrology and carbon balance of an intact raised bog"	T4.2.9 MoonSu Kim: "Study on Naturally Occurring Radioactive Materials (N.O.R.Ms) in Groundwater of Twa Islands with Various Geologic Settings in South Korea"	T6.1.2 Manuel Sapiano: "Optimising the management of the Gozo Mean Sea Level Aquifer (Malta)"		
12:00-12:15	T2.5.10 Max Karen: "The use of hydrogeological assessment for the development of groundwater resource management strategies using the example of the Itawa Springs in Ndola, Zambia"	T2.7.10 Kyung-Jin Lee: "The assessement of urban groundwater hydrochemistry in Seoul, South Korea, using combined pattern recognition methods"	T3.2.10 Marco Pola: "Numerical modelling as a tool to improve conceptual models: the case study of a regional hydrothermal system in NE Italy"	T7.3.3 Tibor Stigter: "Studying the dependence of wetlands and related ecosystems on groundwater in different climatic and hydrogeological settings using multiple tools"	T4.2.10 Marco Petitta: "Test-site monitoring of groundwater and seismicity in Central Apennine (Italy) during 2016-17 earthquakes: pre- and post-mainshock aquifer responses"	T6.1.3 Philip Schuler: "Assessment of multi-level groundwater flow dynamics in the context of Irish karst hydrogeology"		
12:15-12:30	T2.5.11 Malik Peter: "Transmissivity values of pre-Quaternary aquifers based on borehole specific capacity reinterpretation"	T2.7.11 Donald Mead: "Protecting the Karst Te Waikoropupu Springs in New Zealand"	T3.2.11 Pınar Avcı: "Modeling of regional land subsidence due to aquitard drainage in Konya closed sub-basin, Turkey"	T7.3.4 Xihua Wang: "The characteristic of extinction depth of shallow groundwater on the high-latitude region: Case study on the Sanjiang Plain, Northeast China"	T4.2.11 Francesco La Vigna: "The importance of groundwater monitoring for Cities – The example of Rome and its inhabitants involvement"	T6.1.4 Josip Terzić: "Groundwater research on a Dinaric karst island – the island of Vis case study (Croatia)"		
12:30-12:45	T2.5.12 Louise Soltau: "Understanding aquifer characterisation to better define sustainable use: Berg River catchment near Franschhoek"		T3.2.12 Stefano Viaroli: "Use of numerical modelling to test hypothesis on the hydrogeological conceptual models in a complex aquifer: Riardo Plain (Southern Italy)"	T7.3.5 Maria Paula Mendes: "The role of groundwater in cork oak woodlands during the dry season"	T4.2.12 Marielle Van Vliet: "Trend analysis in agricultural groundwater: age dating, gas characterization and antibiotics"	T6.1.5 Moe Henning: "Exploration and Hydrogeological Assessment of a Deep Coastal Aquifer System in Tanzania"		
12:45-13:00	T2.5.13 Makoto Taniguchi: "Groundwater-energy-food nexus for sustainability"			T7.3.6 Xiuyan Wang: "The relationship between shallow groundwater and vegetation development characteristics—A case study of Manas River Basin in Xinjiang, China"	T4.2.13 Michael Rivett: "Use of a simple freeze-coring method to characterise riverbed – hyporheic zone heterogeneity"			
13:00-14:00	LUNCH IN HOTEL RESTAURANT							
14:00-14:30	KEYNOTE BY VIVIANA RE AND RAQUEL SOUSA							
14:30-14:45	THEMATIC LECTURE - TIME SERIES DATA ANALYSIS - SHORT TERM AND LONG TERM FORECASTS OF GROUNDWATER LEVELS BY KRISTIJAN POSAVEC							
		T8.2. Geothermal reservoirs and their potential	T3.3. Using unconventional observation data in hydrogeological modelling	T7.1. Methods for characterisation of groundwater dependent ecosystems	T4.2. Monitoring of groundwater quality and contamination	T8.3. Hydrogeochemistry of thermal and mineral waters		
14:45-15:00		T8.2.1 Ágnes Rotár-Szalkai: "Delineation and characterization of geothermal reservoirs in the Southern part of the Pannonian Basin"	T3.3.1 James Thornton: "Reducing uncertainty in integrated hydro(geo)logical models by incorporating various novel, spatially distributed measurements"	T7.1.1 M. Teresa Condesso de Melo: "Development of a methodology to identify groundwater dependent ecosystems in Portugal for the implementation of the European Water Framework Directive."	T4.2.14 Timotej Verbovšek: "Use of C, O/D, Sr and 3H isotopes for determination of hydrogeochemical processes in Pliocene and Triassic aquifers of the Velenje coal basin, NE Slovenia"	T8.3.1 Marina Ćuk: "Can elevated uranium concentrations in groundwater be predicted?"		
15:00-15:15		T8.2.2 Grant Ferguson: "Groundwater and Unconventional Oil and Gas Developments"	T3.3.2 Pierre Grizard: "Regional Groundwater Model Constrained with 14C Dating: A Case Study in the Endorheic Cretaceous Basin of Tsagaan Els, Mongolia"	T7.1.2 Abraham Springer: "Landscape-Level Methods to Improve Springs Ecosystems Stewardship"	T4.2.15 Marco Rotiroti: "Using Cl/Br ratios and water isotopes to trace aquifer recharge in a highly irrigated area, the Po Plain (N Italy)"	T8.3.2 Nina Rman: "Use of isotopes in exploration of mineral and thermal waters – examples from Slovenia "		
15:15-15:30		T8.2.3 Tamara Marković: "Approach to Exploration of the East Croatian Transboundary Geothermal Deep Water Bodies"	T3.3.3 Ingrid Dennis: "Regional recharge estimation by applying a Genetic Algorithm to various groundwater balance methods"	T7.1.3 Lidija Globevnik: "Large-scale pressures on the chemical status of European groundwater bodies"	T4.2.16 Yun-Yeong Oh: "Wavelet-based multivariate time-series analysis of CO2 flux at soil-atmosphere boundary, with respect to hydro-meteorological factors: Results from a baseline survey at an artificial CO2 leakage experimental site in South	T8.3.3 Daniela Ducci: "Natural Background Levels and geochemical anomalies in groundwater"		
15:30-15:45					T4.2.17 Maria Filippini: "Multi-element isotopic fingerprinting on aqueous-phase chloroethenes derived from chlorinated pitches"	T8.3.4 Zhanxue Sun: "Hydrogeochemistry of hotsprings in northwest Jiangxi Province, SE-China"		
15:45-16:15	COFFEE BREAK IN HALL							
16:15-16:30		T8.2.4 Staša Borović: "Possibilities of finding geothermal water for heating purposes in the Town of Vukovar (Croatia)"	T3.3.4 Rena Meyer: "Direct simulation of environmental tracer (4He, 3H, 14C, δ18O, δ2H) transport in regional-scale aquifers at the 0-40 kyr timescale"			T8.3.5 Maja Todorović: "The study of rare earth elements migration in different hydrogeochemical environments"		
16:30-16:45		T8.2.5 Bridget Scanlon: "Review of Water Risks Related to Unconventional Oil Production in the U.S."	T3.3.5 Oliver S. Schilling: "The worth of unconvetional observations in groundwater model calibration"			T8.3.6 Jana Štrbački: "Migration of essential microelements in different types of mineral waters: Examples from Serbia"		
16:45-17:00						T8.3.7 Gary Robbins: "Radium and Radon Mobilization by Deicing Salt Contamination of Groundwater"		
17:00-19:00	POSTER SESSIONS IN HALL T2							
				Meeting of the Committee of the IAH Italian Chapter	Asian chapters	KINDRA project training session (free and open attendance)	Commission on Groundwater and Energy	GRIPP meeting
20:00	GALA DINNER							

Friday, 29.9.2017

	MARE 1	MARE 2	MARE 3	MARE 4	DUBRAVA 1	DUBRAVA 2	LEVANT	
8:30-9:00	KEYNOTE BY ATTILA KOVÁCS							
	T2.6. Regulatory framework of groundwater management	T6.3. Sea-aquifer relationship – using new and old tools	T6.4. Management of groundwater resources of coastal aquifers	T8.1. Groundwater and Energy	T4.2. Monitoring of groundwater quality and contamination	T8.3. Hydrogeochemistry of thermal and mineral waters		
9:00-9:15	T2.6.1 Johanna Koehler: "A Cultural Theory of Groundwater Risks and Social Responses in Rural Kenya"	T6.3.1 Josip Terzić: "Possibilities of increasing fresh water abstraction on the karst island of Korčula (Croatia)"	T6.4.1 Maurizio Polemio: "A comprehensive approach to the knowledge of the coastal carbonate aquifers of Adriatic and Ionian Seas"	T8.1.1 Grant Ferguson: "Characterizing Permeability in Deep Aquifers"	T4.2.18 Giuseppe Sappa: "Real time karst spring monitoring: first results about the groundwater circulation in the karst aquifer feeding Pertuso Spring"	T8.3.8 Joyce Tryphina Leshomo: "Uranium, Nitrate and Fluoride in drinking water of the Karoo Uranium Province, South Africa"		
9:15-9:30	T2.6.2 MEHMET EKMEKCI: "Challenges and consequences of groundwater development in Turkey: Perspectives on implementation of the EU-water framework directive and the sustainability concept"	T6.3.2 Stephan Seibert: "Characterization of the redox system of freshwater reservoirs below the back barrier island Spiekeroog"	T6.4.2 David Pulido-Velazquez: "Integrated assessment of hydrological impacts of potential future scenarios of climate, land use change and Sea Level Rise on a coastal Mediterranean aquifer. The Plana Oropesa-Torreblanca aquifer."	T8.1.2 Maximilian Frick: "3D coupled fluid- and heat flow modelling of the subsurface of Berlin, Germany"	T4.2.19 Ahmad Taufiq: "Estimating groundwater mixing ratios using hydrogeochemistry parameters and nitrate isotopes due to excessive groundwater pumping in the Bandung basin, Indonesia"	T8.3.9 Patrick Lachassagne: "Explaning the CO2 and mineral water journeys from the earth mantle to subsurface carbogaseous aquifers and springs"		
9:30-9:45	T2.6.3 Lucio Martarelli: "Common and different features of Chinese and Italyn hydrogeological mapping guidelines"	T6.3.3 Yoseph Yechieli: "Direct determination of the rate of seawater intrusion with noble gases"	T6.4.3 Judith Flügge: "Water Management in Coastal Areas under the Conditions of Climatic and Demographic Change at the German Coast"	T8.1.3 Stefano Lo Russo: "Influece of dynamic viscosity in geothermal Open Loop Systems modelling"	T4.2.20 Vojo Mircovski: "Hydrochemical characteristics of the groundwaters in Prilep's part of Pelagonia valley– Republic of Macedonia"	T8.3.10 Sebnem Arslan: "Gas geochemistry studies in geothermal and mineral waters of Mugla (SW Turkey)"		
9:45-10:00	T2.6.4 Jelena Loborec: "Specific vulnerability assessment in karst system, example of Jadro and Žrnovnica springs catchment area, Croatia"	T6.3.4 Satoshi Ishida: "Distribution of groundwater age and fluctuation of NO3-N concentration in groundwater in the reservoir area of Sunagawa underground dam, Miyako Island, Japan."	T6.4.4 Salvatore Carrubba: "ACVM (Aquifer Comprehensive Vulnerability Mapping) - A new tool for assessing potential impacts on the sustainability of coastal aquifers and habitats."	T8.1.4 Mohammadreza Jalali: "A Multi-scale Approach toward understanding the Hydraulic Characteristics of the Stimulated Fractured Crystalline Rock"	T4.2.21 Shiyi He: "Study on Carbon sequestration flux and its annual dynamic variation in watershed systems of Yangtze River, Yellow River and Pearl River, China "	T8.3.11 Elena Kayukova: "Hydrogeochemical study of mud volcanoes in the Eastern Crimea"		
10:00-10:15	T2.6.5 Andrew Ross: "Making the transition to conjunctive water management"	T6.3.5 Emily Hepburn: "Origins of groundwater salinity at Fishermans Bend, Australia: Evidence from groundwater ages, stable isotopes and tidal influences"	T6.4.5 Leticia Baena Ruiz: "Assessment of seawater intrusion problems (status and vulnerability) at different spatial scale. Contribution to the analysis of coastal aquifers in accordance with the WFD."	T8.1.5 Stefano Viaroli: "Groundwater budget calculation of the Riardo Plain aquifer (Southern Italy) for conjunctive sustainable uses."		T8.3.12 Anita Erőss: "Flow system analysis of the Villány thermal karst area, Hungary"		POSTER SESSIONS IN HALL T4, T7
10:15-10:30	T2.6.6 Brent Bowerman: "Proactive Water Communication by Oil and Gas Operators in Western Canada"	T6.3.6 Rattana Thirathititham: "Water-rock interaction in Eocene aquifers of Qatar: Hydrochemical evidence of dedolomitisation driven by gypsum dissolution."	T6.4.6 Dragan Radojevic: "Development of groundwater vulnerability model for the purpose of regional spatial plan of Montenegrin costal area"	T8.1.6 Maciej Kłonowski: "Safety of groundwater resources in terms of development of shallow geothermal energy installations"				
10:30-11:00	COFFEE BREAK IN HALL							
11:00-11:15	T2.6.7 Daniela Benedicto van Dalen: "The Groundwater Game: A Serious Game on Improving Groundwater Management through Cooperation and Collective Action"		T6.4.7 Vincent Post: "Evaluation of management rules for the sustainable management of freshwater lenses using script-based models"					
11:15-11:30	T2.6.8 Kornelius Riemann: "Unitisation – a Community-Based Approach to Aquifer Management"		T6.4.8 Roland Barthel: "Groundwater management in coastal zones and on islands in crystalline bedrock areas of Sweden"					
11:30-11:45	T2.6.9 Andreas Antoniou: "Indicator based approach to prioritise transboundary aquifers at risk from development stress, pollution or climate change"		T6.4.9 Nils Moosdorf: "Societal use of submarine groundwater discharge: Examples of an underresearched water resource"					
11:45-12:00	T2.6.10 Jeroen November: "Tackling illegal groundwater abstractions: A must for groundwater governance"							
12:00-13:00	LUNCH IN HOTEL RESTAURANT							
13:00-14:00	CLOSING CEREMONY							

Keynotes

Alice Aureli

Groundwater: preserving our natural heritage for sustainable development

To preserve the equilibrium between human and nature is the base for sustainable development. The Planet's water security greatly depends on our capacity to manage and preserve our groundwater resources heritage for the generations to come. UNESCO seeks to encourage the identification, protection and preservation of cultural and natural heritage of outstanding value to humanity. This is embodied in the World Heritage Convention adopted by UNESCO in 1972 that links together the concepts of nature conservation and the preservation of cultural properties. The Convention recognizes the way in which people interact with nature, and the fundamental need to preserve the balance between the two. Our cultural and natural heritage are both irreplaceable sources of life and inspiration.

In a context where global water demand is projected to increase by some 55% by 2050, water security rhymes with groundwater. Better knowledge of the aquifers and good governance of groundwater resources can contribute to fix water security. Climate Change Studies should also take more consideration of the possible impacts on the hydrogeological cycle. While Equality is one of the pillars of Sustainable development, not all human beings face these water security risks the same way. Access to clean water is recognized as a human right, however today 884 million people still lack even a basic drinking-water service. Water stress affects more than 2 billion people around the world, and it is a figure that is expected to rise. Inequalities are increasing around the world on many other domains (UNESCO, Social Sciences report, 2016). Sixty-two richest individuals owned as much as the bottom half of humanity (Oxfam, 2016). On 25 September 2015, all countries of the world adopted at the UN General Assembly an agenda to reduce inequalities, the Sustainable Development Goals (SDGs) agenda, which aim to end poverty, protect the planet and contribute to ensure prosperity for all. Challenging inequality is at the heart of the SDGs, with their commitment to "leave no one behind". In this framework countries have to provide from now to 2030 detailed information about their national and transboundary surface water and groundwater to the UN system to allow a better monitoring and management of the resources.

Barbara Čenčur Curk

Coarse gravel aquifers – from detailed studies to management of drinking water supply

The Ljubljana field aquifer is one of the biggest unconfined porous aquifers in Slovenia and is a very important drinking water source. More than half of the aquifer area lies below the city, thus there is several decades of evidence showing changes in groundwater quality and quantity. The most endangered water well field is Hrastje, where human activities in the area degraded groundwater quality in the past. The aquifer consists of very coarse gravel (particle sizes ranging up to 50 mm and more) and is very heterogeneous. The heterogeneities consist of several clay and conglomerate lenses, which drive the parameter variability and create large uncertainties reflecting complicated hydraulic and chemical processes. Therefore, detailed studies of these processes have to be performed on a small and large scale.
For determining water transport in variably saturated porous media we need the soil water retention curve and the hydraulic conductivity function. A combination of the simplified evaporation experiment (HYPROP) and the dew point method (WP4 PotentiaMeter) was used to obtain the information across a wide moisture range on natural, albeit adjusted samples (sieved to fine (diameter <2 mm) and coarse (diameter <8 mm) samples). Results on coarse samples were compared with the calculated results according to mass-based gravel correction. In order to study pollution transport, several tracer experiments were carried out in the past. Despite a great risk, the experiments were performed on the catchment area of the Hrastje waterworks, inside the second water protection zone. During the experiments the water from Hrastje waterworks was still in use for drinking water supply. A water supply management system regarding optimization of water extraction and land use restrictions under climate change scenarios was set up. Several management options regarding water quantity were selected and evaluated: (i) establishing of new water well field, (ii) artificial recharge with infiltration wells, (iii) implementation of farming restrictions in the first and second safe guard zone (compensations because of lower farming production) and (iv) drinking water treatment.

Viviana Re & Raquel Sousa

Responsible (ground)Water Scientists – A heritage for future generations

Sustainability, management, protection, stress, waste, pollutants, cooperation, development, are some of the most frequently used keywords in hydrogeological publications and talks. Every time we present or write about our work and research results, we almost always find ourselves discussing water distribution on earth, the global water crisis and the need for sustainable water resources management. As scientists we often tell people the importance of saving water, recycling and reducing pollution, and certainly we aim to use the best available scientific tools for providing this information. But when it turns to our daily life, how often do we question if we are actually living in a sustainable way? Are we really acting to ensure safe water resources, for the future generations? Knowing we are living in an increasingly water dependent world and that our food and good consumptions depend on water, is there something we can do to contribute successfully diminishing our water and ecological footprint?

Being aware of the strong interconnection between human activities and groundwater, hydrogeologists are becoming more and more involved in supporting science-based management practices and outreach activities targeting environmental protection worldwide. But it is also by taking direct action in reducing the impact on natural resources in our own daily life, that we can improve our credibility to the general public and civil society. Indeed, by acting in a manner consistent with the outcomes and projections of our research, we will contribute to bridging the gap between science and society and creating a network of mutual trust with (ground)water end-users.

This talk will explore the challenges and opportunities for a new generation of Responsible (ground)Water Scientists, discussing actions to make hydrogeologists real advocates of groundwater protection for a more sustainable world, and help drive the changes inspired by their research.

This presentation is the first keynote lecture by two Early Career Hydrogeologists as invited speakers. The ECHN and IAH-Council hope this will become a new tradition during IAH congresses, contributing to showcase the work carried out by the new generation of groundwater professionals and strengthening the interactions between early career and senior hydrogeologists.

Anker Lajer Højberg

Combating nitrogen by accounting for natural degradation

EU member states are challenged by nitrogen loads to groundwater and estuaries/inland freshwater systems impeding the achievement of good ecological status as required by the Water Framework Directive (WFD). Nitrogen regulation are commonly based on uniform regulation imposing the same restriction for all areas independent on drainage schemes, hydrogeochemical conditions in the subsurface and retention in surface waters. Recent research projects have, however, illustrated that natural degradation of nitrogen may be significant but with large spatial variations depending on the physical and biogeochemical conditions. A much more cost-effective regulation of nitrogen is thus possible if areas with high and low reduction can be identified, allowing to differentiate regulation putting most restrictions and mitigation measures in areas, where nitrate leaching is high and natural nitrogen reduction is low. Present challenges include the mapping of spatial variability in natural nitrogen degradation at sufficient small scale and with sufficient accuracy and the development of a concept by which the natural degradation can be accounted for in the regulation of nitrogen. These issues have been the topics for several recent research and innovation projects in Denmark, and the talk will draw on experiences and results from these studies.

Attila Kovács

The use of hydrograph analysis for the characterisation and modelling of karst systems

Karst aquifers are complex hydrogeological systems with strong heterogeneity originating from the presence of dissolution channel networks. Heterogeneity manifests in the duality (diffuse and concentrated nature) of the hydraulic processes taking place in karst, including recharge, groundwater flow and discharge.

The quantitative characterisation and numerical modelling of karst hydrogeological systems requires the definition of realistic hydraulic and geometric parameters. For this reason, equivalent medium modelling approaches have limited applicability in karst hydrogeology. Direct information on conduit network geometry is rarely available, and classical geological, geophysical and hydrogeological methods provide only limited information on the spatial configuration of hydraulically active conduit networks.

However, in most cases spring and/or well hydrograph data, together with well test results are available, or relatively easily obtainable.
Hydrograph analytical methods include time series analysis and single event analysis. While time series analytical methods are usually used for forecasting, data completion, and correlation analysis, single event methods based on analytical solutions can provide quantitative information on hydraulic and geometric characteristics of karst systems.

Novel analytical methods establish links between aquifer properties and hydrograph characteristics. Both spring and well hydrographs contain important information about the hydraulic functioning of karst systems. A conceptual model with two permeability classes adequately describes the hydrodynamic behaviour of karst.

Generally, spring hydrograph analytical techniques can provide information on the characteristic hydraulic parameters and conduit spacing of a karstic catchment, while well hydrograph analysis usually provides information on the hydraulic and geometric characteristics of individual matrix blocks. The combination of spring and well hydrograph analytical techniques provides a powerful tool for the characterization of the structure and hydraulic functioning of karst systems, as demonstrated on various test sites. Parameters estimated through hydrograph analysis can be fed into numerical groundwater models. Strongly heterogeneous hydrogeological systems can be quantitatively classified based on hydrograph analysis.

Božidar Biondić

Water resources of Dinaric karst areas in Croatia

Dinaric karst water resources in Croatia have a great importance for the development of the country because nearly half of the onshore part of the country is built of the great mass of carbonate rocks formed on one of the platforms in the zone of subduction between African and Euroasian tectonic plates. Dinarides, stretching from southern parts of the Alps over Croatia, Bosnia and Herzegovina to Montenegro, are creating a unique megastructure of uniform geologic characteristics. Origin, geological and tectonic events, erosion processes and sea level changes have caused the development of karst processes of intensively fractured carbonate rocks and specific surface and underground network of water flows. This is an area rich in rainfall and aquifers, from which are supplied numerous towns and villages in mountainous and coastal Adriatic area with drinking water. Intensive water dissolution of carbonate rocks creates visually very attractive spaces, parts of which are designated as National parks. Karst area is generally poor with surface water, which are mainly related to karst fields or the edges of the high parts of Dinaric area. Real wealth is groundwater, which drains to a large karst springs after a relatively short retaining in underground with high apparent velocities. Regardless of the natural high karst aquifers, natural vulnerability and relatively short retaining of water in karst underground, the groundwater quality is high and is practically used with a minimum treatment in the water supply of the population. Presentation will be focused on the origin and the geological events at Dinaric platform, origin and spatial distribution of water resources, the emergence of large karst springs, water quality in karst catchments, ways of the water use and problems with the water in these areas, especially the sustainable protection of water quality including impact of the sea in coastal areas and on islands, especially in condition of expected global climatic changes.

Neven Krešić

Groundwater Remediation: From Hydrogeologic Site Concepts to Applied Numeric Models

The cleanup of various sites with groundwater contamination has been a major element of professional hydrogeology in the United States and, increasingly, in other countries around the world. It is likely that every professional hydrogeologist will work on a groundwater remediation project at some point in her or his career. The most critical element for success of such projects is development of hydrogeologic conceptual site models (CSM) which should be viewed as continuously evolving throughout the entire process, with every new piece of information. Similarly, a hydrogeologist evolves together with the CSM and accepts a possibility of initially "being wrong". This flexibility is particularly important for groundwater remediation projects although CSMs for other, non-contaminated sites, share many of the same elements (e.g., where is the groundwater coming from, where is it going, how much of it, how fast…). At the same time, applied numeric models of groundwater flow and contaminant fate and transport have become an integral part of all phases of groundwater remediation projects including CSM development (remedial investigation) and remedy selection and implementation (feasibility study and remedial design). There is positive feedback between numeric groundwater models and CSMs – models can guide collection of additional data and also fill in the gaps between data that have been or will be collected at discrete time intervals, thus helping the hydrogeologist better understand and simulate transient (time-dependent) processes. This presentation focuses on different elements of CSM (groundwater and contaminant characterization) that are needed for numeric simulations of a variety of remedial alternatives including pump-and-treat or groundwater interception, natural attenuation, impermeable barriers or permeable reactive barriers, thermal remediation, and others. Models are crucial in answering critical questions in groundwater remediation: is the technology feasible, how long the remediation will last until it reaches its goal, and how much will it cost?

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Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Groundwater heritage: the Holy wells of Ireland

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KEY WORDS Groundwater heritage, holy wells, GIS, water and health

ABSTRACT
Groundwater heritage is concerned not only with protecting our groundwater resources for future generations, but also with the wells which we use to abstract our groundwater supplies. In addition to their practical value, many wells have social, historical and cultural significance. Wells have been sites of veneration since the earliest times. There are references to wells in sacred texts such as the Bible, the Koran and the ancient Vedic scriptures in India. In Ireland there are about 3,000 holy wells. Some pre-date Christianity and were subsequently adopted by the new religion from the 5th century onwards; others are much more recent. Many of these holy wells are still visited regularly by pilgrims seeking cures for various ailments, whereas others are overgrown and inaccessible, or have even been destroyed altogether by construction works. A GIS-based analysis indicates that the holy wells are found in all of the main lithological units in Ireland, ranging from Precambrian metamorphic rocks, to Ordovician volcanics, Carboniferous limestones and shales, to Quaternary sand and gravel deposits. Whereas about 25% of the wells are located in aquifers classed as Regionally Important, the remaining 75% occur in Locally Important or Poor aquifer classes. The GIS analysis has been followed by hydrogeological appraisals of individual wells (80 to date). These appraisals have confirmed that the majority of holy wells are springs or shallow spring wells. A selection of wells have been sampled for major ions and trace elements, and the results compared with national background levels for these parameters, to see if there are any anomalies. Some of the hydrochemical findings will be presented at the congress. The focus is on those parameters that potentially might have implications for human health.

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Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

The Springs of the City of the Cape Town – Heritage and proposed spring use strategy

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KEY WORDS Spring, sustainable use

ABSTRACT

The City of Cape Town has a very strong link to the water flowing on the slopes of Table Mountain. The Oranjezicht springs (notably the Stadsfontein) are most well-known of these. The earliest inhabitants, the Khoikhoi usually arrived in the Peninsula in November because there was grazing for the cattle and water due to the perennial nature of the spring. In 1647 a Verenigde Oost Indiesche Compagnie ship, the Nieuwe Haarlem, stranded at the Cape. Some of the crew were left behind for almost a year to look after the salvaged cargo. They recommended the Cape as a refreshment station due to the fertile soils, abundance of fresh water, the possibility of trade with local tribes for meat, the abundance of wild life including fish and wood in the Liesbeek valley (Schoeman, 2009). The VOC settled in the Cape in 1652. The vegetable gardens were established using the water from the Oranjezicht springs. Infrastructure in the form of lead pipes was installed in 1707 by van der Stel to prevent pollution of water at source. Piped water was supplied to affluent households by the early 1800s (Mäki, 2008). These springs and others were the sole source of drinking water supply in the Cape until 1891 (Kotze, 2010).

Some water reservoirs were built during the 19th century and were supplied with pipes from the Oranjezicht springs, Waterhof spring and Kotze spring (Harris, 2002). Cast iron pipelines were used to distribute water within the city (Kotze, 2011). The poorer citizens, including slaves, were supplied with water at a number of fountains in the city. The streams (likely spring-fed) from Table Mountain were at this time solely reserved for domestic use (Mäki, 2008). The 36 free-flowing fountains in the city were considered a great waste of money. The engineer of the time, John Chrisholm suggested it be replaced with hand-pumps – motivating that if people work for the water they will appreciate it. (Mäki, 2008).

The Stadtsfontein Spring (original Main Spring) has been used sustainably since the mid-1800s. The spring was enclosed in 1813 and the water was then piped in 1853 to a collection chamber (New Main Spring) together with water from the nearby Vineyard, Lammetjie and Kleintuin Springs. The water from the Oranjezicht Springs has been consistently used, even though it was plagued with water quality concerns from early on. The long term flow monitoring data that was obtained from the City of Cape Town (CCT) is shown in Figure 1. From this plot the cyclical nature of the spring flow and rainfall can be clearly seen. There is a lag of 2 -3 months between rainfall and increased flow and it is assumed the springs occur under confined conditions and as the water infiltrates in the mountain the pressure increases down gradient and increases flow. This increase in flow and pressure occurs after 2 – 3 months. The actual recharge of the water has been determined using stable isotope ratios of deuterium (δD) and Oxygen 18 (δ18O). Though the spring data is limited, it has been calculated that it takes about 3 years for 50 % of the recharge (actual water inflow) to reach the spring discharge points (Harris et al, 2010).

Code of abstract: T1.1.3
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Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

The Value of Groundwater and Groundwater Heritage

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KEY WORDS - groundwater, awareness, economic valuation, benefits

ABSTRACT
Globally, invisible groundwater resources are under increasing pressure. Management response to this pressure is often not adequate, also due to limited awareness of the importance of groundwater resources. Since we live in the world geared by market economy, the economic valuation of groundwater would be an excellent awareness instrument. However, public goods like groundwater are often prone to market failure because they have elements of both market and non-market goods/services. The costs of groundwater developments are just a part of total societal and environmental costs: for example, preservation for future generations and ecological externalities not compensated via the market mechanism count as well. Economic valuation -built on maximising benefits- has other challenges as well, such as estimation of environmental benefits and welfare distribution. Nevertheless, economic valuation can provide valuable insights in groundwater services, water allocation, stakeholder preferences and possible changes in benefits/value of groundwater.
A framework for using value of groundwater in decision making has been developed and tested by IGRAC. The value of groundwater is mostly influenced by costs of groundwater development, willingness to pay and availability of alternatives. Alternatives should always be considered when building development scenarios. Also, only differences between scenarios can be valued, not the absolute value of groundwater storage.
Groundwater valuation becomes even more challenging – and rewarding - when it comes to internationally shared aquifers: more aware the aquifer states are of common risks and benefits, a stronger will be incentive to adequately manage the common resources. The suggested valuation framework is tested on two transboundary aquifers; although data scarcity shows again to be a limiting factor, it cannot prevent the economic valuation emphasizing benefits from invisible groundwater; economic valuation of groundwater might not be able to deliver exact figures but it does provide valuable contribution to decision making process. Making benefits from groundwater (and risks of wrong decisions) more obvious and quantifiable makes invisible groundwater more visible and hence closer to our attention: a necessary condition for preserving our heritage.

Code of abstract: T1.1.4
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

An over exploited alluvial shallow aquifer in arid area : threat and perspectives. Case of Feija (Morocco)

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KEY WORDS - arid climate – over exploitation- irrigation – scarcity.

ABSTRACT

The plain of Feija is a moderate topography area nestled between two elevations in mountainous arid climate zone. In this oasis region, annual precipitation varies between 60 and 100mm, with a potential evapotranspiration, around 3000mm. Groundwater resources flow in a generalized shallow aquifer composed of altered shale overlaid by alluvial formation.

This aquifer was lowly solicited in the 1980s. It's started to supply drinking water to the town of Zagora in 2002. The production of one of the boreholes is about 20l/s.

The area has seen the emergence of a new lucrative agricultural activity. Indeed the production of watermelon has become a very important source of income that led to an increase in irrigated areas, and therefore intense solicitation of groundwater.

The comparison between 2014 and 1980 piezometric situations -made by the Basin Agency- due to a decline in rates for the drinking water supply (decrease about 80%), shows drawdown of water levels until to 21 m. The saturated thickness of this aquifer doesn't exceed 36 m. Therefore, the difference between in flow and out flow shows a deficit of 5Millions M^3 per year. If this rate of exploitation is maintained it would lead to the drying up of this aquifer in two decades.

The purpose of our study is to develop a mathematical model of this threatened aquifer. Simulations were carried out under different scenarios. They made it possible to estimate the drawdown and to elaborate a strategy to be able to perpetuate this resource and consequently to save the activity in this disadvantaged zone and to continue to supply the city of Zagora.

Code of abstract: T1.1.5
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Cause for spatial variation in tritium concentrations of groundwater in the southern coastal region of Fukushima, Japan

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KEY WORDS tritium, sulfur hexafluoride, spatial variation, groundwater, rainwater, Fukushima

ABSTRACT
Tritium is one of the radionuclides emitted through the accident at the Fukushima Daiichi Nuclear Power Station (F1NPS) in 2011. The effects of tritium in groundwater systems around the F1NPS are not well understood. This presentation discusses the cause of spatial variation in tritium concentrations in groundwater, collected at wells in the southern part of the F1NPS through three field campaigns in 2012. These wells are distributed southwestward at 21 to 54 km from the F1NPS and can be regionally divided into five groups. Measured tritium concentrations were in the range of 1.1 to 12.9 tritium unit (TU) and were much lower than the World Health Organization limits for drinking water. Additionally, the concentrations were different among the groups and higher concentrations were measured in the relatively shallow wells of the groups near the F1NPS. Tritium concentrations in rainwater were elevated after the F1NPS accident and returned to the background level within five weeks (Matsumoto et al., 2013). Mixing of contaminated rainwater with groundwater was considered responsible for the spatial variation. Temporal changes in tritium concentration in rainwater at 25- and 50-km points from the F1NPS were estimated based on temporal variation of actual measured tritium concentrations in rainwater and spatial variation of atmospheric tritium activity by Matsumoto et al. (2013). Weighted means of tritium concentration in rainwater within five weeks after the accident were 463 TU at 25 km and 148 TU at 50 km from the F1NPS. Assuming that rainwater of these concentrations mixed with groundwater (background tritium concentration of groundwater was considered to be 3 TU) in a well at which the water level was three meters above the well bottom, the resulting tritium concentrations would be 11 TU at 25 km and 6 TU at 50 km. These concentrations were comparable with the measured values, indicating that the spatial variation in tritium concentrations in groundwater was caused by the mixing of rainwater with elevated tritium concentrations after the F1NPS accident.

Code of abstract: T1.1.6
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Influence of air pollution on rainfall chemistry and impacts on groundwater quality in the Milan urban area, Italy

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KEY WORDS - air pollution, rainfall chemistry, groundwater contamination, numerical modeling, Milan

ABSTRACT
It is renowned that rainfalls reduce air pollution in the troposphere, since contaminants are captured and dissolved by rain drops or involved in the formation of particulate matter. Consequently, a fraction of rainfalls infiltrates through ground surface and migrates through the vadose zone, contributing to groundwater contamination.
The path air–rainfall–infiltration water–groundwater is observed and analyzed in Milan and its surroundings, covering an area of 3000 km^2, where both urban areas and agricultural activities are extensively present. The reconstruction of the path is carried out following the procedure:
1) Collection of rainfall samples related to the same rainfall event at 12 monitoring points covering the entire study area. Rainfall collection is repeated several times during the year at all monitoring points or during the same rainfall event in a single monitoring point.
2) Chemical analyses of rainfall samples to determine major anion concentrations (e.g., NO_3^-, SO_4^{2-}, Cl^-).
3) Comparison of rainfall chemistry and air pollution, to evaluate the influence of air pollution on rainfall quality.
4) Implementation of a numerical model to evaluate the amount of contaminant infiltrating through the vadose zone. The numerical model will consider different hydrogeological and environmental contexts in the study area (i.e., urban and agricultural environments).
Preliminary results of the first rainfall collections have shown a direct relationship between high levels of air pollutants (NO_2 and SO_2) in the atmosphere and relatively high contaminant concentrations (NO_3^- and SO_4^{2-}) in rainfall samples. Rainfalls sampled at the beginning of the precipitation, especially after a long dry period, show higher contaminant concentrations respect to those sampled at the end of the precipitation window. Differences in rainfall samples depend on the location of the monitoring point (urban vs agricultural areas), proximity to emission sources (e.g., traffic roads), meteorological conditions (intensity and wind direction).
Then, the numerical model uses contaminant concentrations in rainfalls to identify anthropogenic background values of pollutants in groundwater, not related to direct sources of contamination (e.g., industrial wastes, leakages from the sewage systems and fertilizers).

Code of abstract: T1.1.7
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Mechanisms of groundwater level changes after the 2016 Kumamoto earthquake

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KEY WORDS - groundwater level change, Kumamoto earthquake, active fault, coseismic strain change, flow path change

ABSTRACT

Significant groundwater level change was observed after 2016 Kumamoto earthquake. Since groundwater monitoring network is quite dense, Kumamoto area is very attractive field to study groundwater level changes by large earthquake. Thus, this study aimed to reveal these mechanisms by analyzing coseismic groundwater level changes together with strain calculations. Citizens of Kumamoto entirely depend on groundwater for drinking purpose, therefore, this study is also important with prospective how the earthquake influence to groundwater environment in this area. Foreshock occurred on 14 (M 6.5) and mainshock occurred on 16 (M 7.3) April 2016. We obtained the groundwater level data in digital at every 60 minutes from 1st April 2015 to 31th December 2016. Among these data we used monitoring results during 1st April 2016 and 31st May, 2016, in which duration effect of seasonal variation in groundwater level could fairly be neglected and observed groundwater change could regard as influence of the earthquake.

Crustal strain volume, which was calculated at the screen depth of each monitoring well based on crustal deformation volume and fault distribution, was ranging between -4.29×10^{-6} and 3.71×10^{-5} in confined aquifer after the mainshock. The result showed that almost all monitoring sites are placed as strong extensional fields, in which range the crustal structural deformation can occur. Overall, groundwater level changed in most of the wells after the earthquakes and were remarkably changed in confined aquifer. After the mainshock, the groundwater level fall with the maximum decline of 4.7 m within an area between near the epicenter to the 22 km north point. On the contrary, in the eastern part of the study area water level gradually recovered and turned rose up with maximum increase of 2.6 m after 14 days from the mainshock. Distribution of the well showing clear groundwater level drop off corresponds well to the locations of new active fault caused by the earthquake. Therefore, we conclude that the groundwater level decline was due to the formation of new flow paths along the active fault. Further, observed ascending feature in groundwater level at eastern part might be attributed to a change of hydrogeoloic rejime of behind mountains and/or unsaturated zones, resulting movement of water from mountainous aquifers/soil water.

Code of abstract: T1.1.8
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Time Series Data Analysis – Short Term and Long Term Forecasts of Groundwater Levels

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KEY WORDS time series, groundwater level, trend, recession, forecast

ABSTRACT

It is human nature to comprehend natural processes around us in order to have better control over them. Not knowing how much resource we have available for use, especially if it's vital for human existence, live us blind, and helpless in case the resource runs out. Many aquifers around the world experience declining trends of groundwater levels, pointing to continuous diminishing of available groundwater reserves. Besides continuous monitoring, short term and long term forecasts of groundwater levels are essential in controlling the status of groundwater reserves as well as planning the water supply for the current and future generations.

Since many of today's wells for water supply are built decades ago when groundwater levels were generally higher, their screens have or may become partly or fully dry, especially during drought periods which, due to climate changes, tend to have longer durations. In these instances, capacities of those wells decreases and optimization of pumping or even alternative solutions should be searched. In such scenarios short term forecasts can be of use in planning of water supply. Time series data analysis methods like for example recession analysis methods and accompanying tools, which can be used to forecast the worst case scenarios, i.e. continuous recessions in long term drought conditions, can be of use in dealing with such short term forecasts.

Long term forecasts are though, although important for current generation, of greater importance for future generations and groundwater heritage we live behind. If they show continuous declining trends of groundwater levels, they can mobilise decision makers to search for solutions and undertake steps which will prevent further declining in order to provide long term stable water supply. These solutions usually do not come over night since they may include infrastructure projects which require significant amount of financial resources and time required for their planning, designing and construction. Therefore, it is of importance to identify such continuous declining trends in early stages so that appropriate solutions can be developed before the wells run dry. In these instances, trend analysis methods and tools can be of use.

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Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Development of the subsurface heat island beneath Bratislava city.

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KEY WORDS urban heat island, groundwater, temperature, land use, correlation

ABSTRACT
Groundwater temperatures in shallow aquifers are closely linked to urban structures. In many cities elevated heat flux from manifold anthropogenic sources stimulates growing subsurface temperatures. As a result, large-scale subsurface heat islands develop, which substantially change the physico-chemical and ecological conditions in urban aquifers. In our study, we focus on the conditions in the city of Bratislava in Slovakia, where productive aquifers are hosted by the sediments in the Danube river valley. At selected wells, long-term groundwater temperature measurements have been recorded since the year 1991. These temperature time series are measured in shallow depth and therefore show substantial seasonal variations. Long-term air temperature and Danube river temperature are being recorded since 1960, and so trends over the span of 54 years can be evaluated. Each groundwater temperature time series is compared to air temperature, Danube river temperature and also to satellite-derived land surface temperature trends. A clear correlation is found that supports the strong coupling between atmospheric, land surface and groundwater temperatures. Additionally, it is possible to analyze the main differences between generally increasing temperature trends for all selected wells. In our study, a focus is set on the type of land use, urban infrastructures and their role for groundwater temperature evolution. A strong correlation between building density and elevated groundwater temperature indicates that urban underground heat losses are the primary cause of the observed heat island beneath Bratislava.

Code of abstract: T1.1.10
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Using a multipronged approach for assessing temporal and spatial trends of nitrogen transport in the subsurface in an agricultural watershed in Atlantic Canada

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KEY WORDS nitrate, agriculture, temporal and spatial trends

ABSTRACT
A good understanding of the link between the agricultural management practices and the timing and spatial extent of the impact on groundwater quality is required for assessing nutrient heritage and sustainably managing groundwater resources. In this research, temporal and spatial trends of nitrate distribution in groundwater were investigated using a multipronged approach involving water quality monitoring, hydraulic testing and geophysical investigations in conjunction with various modelling approaches. The study took place in Black Brook Watershed, a small (14.5 km2) agricultural watershed in Atlantic Canada. 88% of the 3200 samples collected between 2008 and 2015 showed nitrate levels above the guideline for protection of aquatic life (3 mg NO3 L-1). Hydraulic and geophysical surveys indicate that the calcareous shale aquifer is fractured and anisotropic and the hydraulic conductivity is decreasing several orders of magnitude with depth. The shale has insignificant matrix porosity and thus, the fractures play a dominant role in rapidly conveying the water that is infiltrating through the overlying thin layers of soil and glacial till. This has been confirmed by the rapid changes in water table level, the magnitude of change (up to 12 m), and by the changes in ion concentrations and isotopic composition (water and nitrate) during recharge events. Analysis of long-term nitrate concentrations revealed no significant trend, and this has been explained by the relatively stable acreage and fertilizer amounts used during the monitoring period. Nitrate concentrations showed lower concentrations in the upper portion of the watershed (2.1 mg NO3 L-1), which is mainly forested, with a gradual increase towards the outlet of the watershed (7.8 mg NO3 L-1). The aquifer waters are generally well mixed, with a trend of lower nitrate concentrations at larger depths, and this has been attributed to increased potential for denitrification as evidenced by the low dissolved oxygen content. Nitrogen and oxygen isotopes indicated that nitrate in ~70% of the samples is derived from either inorganic fertilizers or nitrate produced in soil, a result confirmed by a transient groundwater numerical model which links the increased concentrations of nitrate to the dominant crops in the watershed (i.e. potatoes and field pea).

Code of abstract: T1.1.11
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

The Research of PCA –APCS- MLR Method in Regional Groundwater Pollution Solution Quantitative Analysis

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KEY WORDS: *PCA; APCS-MLR; Pollution quantitative analysis; Groundwater; Spatial distribution*

ABSTRACT

Groundwater as a kind of global scarcity freshwater resource, its safe quality, pollution prevention and control has been one of the hottest issues concerned by all over the world, how to analyze the pollutant source solution quickly and accurately, identify the pollution source and estimate relative contribution of the pollutants are important measures for guarantying drinking water safety and sustainable development of ecological environment.

This paper took Limin water source in Harbin Heilongjiang province as an example, collecting 83 samples of water quality sampling points and analyzing 16 key indexes of groundwater quality in the area. Groundwater pollution solution which was done on the basis of improved Factor Analysis (FA) and Principal Component Analysis (PCA) receptors and Absolute Principal Component Score Multiple Linear Regression model (APCS-MLR) provision coupling calculation and the water quality and water chemistry statistical analysis. The results showed that groundwater elements such as nitrogen, phosphorus and iron exceeds bid badly, evolution of groundwater quality were influenced by human activities greatly in the area. The results of pollutant source solution which used the improved FA-PCA-MLR method showed that 4 kinds of main pollution factors including leached migration natural factor, geological environment background factor, agricultural pollution factor, regional typical fluoride impact factor and industrial activity influence factor, the contribution rate is 36.41%, 15.61%, 9.90%, 9.01% and 5.63% respectively, the cumulative variance contribution rate is 79.57% totally. APCS- MLR receptor model results showed that discharging of industrial and living sewage wastewater and fertilizers used in agricultural production were main pollution sources of groundwater, they throughout the north and west regions of middle and lower reaches of Songhua river basin in the study area, the improved FA-PCA-MLR model has a good applicability for groundwater pollution solution.

Acknowledgments: this work was supported by the National Natural Science Foundation of China (No. 41402211 and No. 41372233), the Major Science and Technology Program for Water Pollution Control and Treatment of China (2014ZX07201-010).

Code of abstract: T1.1.12
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Identification of Groundwater Level Decline since the Seventies of the Twentieth Century – Casey study of the Zagreb and Samobor-Zaprešić Aquifers, Croatia

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KEY WORDS groundwater level, decline, trend, water supply

ABSTRACT
Historically, groundwater levels of the Zagreb – Velika Gorica and Samobor – Zaprešić aquifers are continuously declining. Figure 1 presents isopach map of ground water level decline, showing that groundwater levels declined up to 5 m on some parts of the aquifers during the last 40 years.

Continuous decline of groundwater levels mainly occur due to continuous dominant erosional processes of the Sava riverbed, i.e. the river transports existing riverbed deposits downstream from Zagreb. Due to lack of sediment transport from the upper parts of the river, where it is regulated by hydropowerplants, the river cuts its course into existing gravel deposits. Decrease in the Sava riverbed causes decrease in water levels of the river, and consequently in groundwater levels of Zagreb – Velika Gorica and Samobor-Zaprešić aquifers, since groundwater level, i.e. water table is permanently connected to the Sava river.

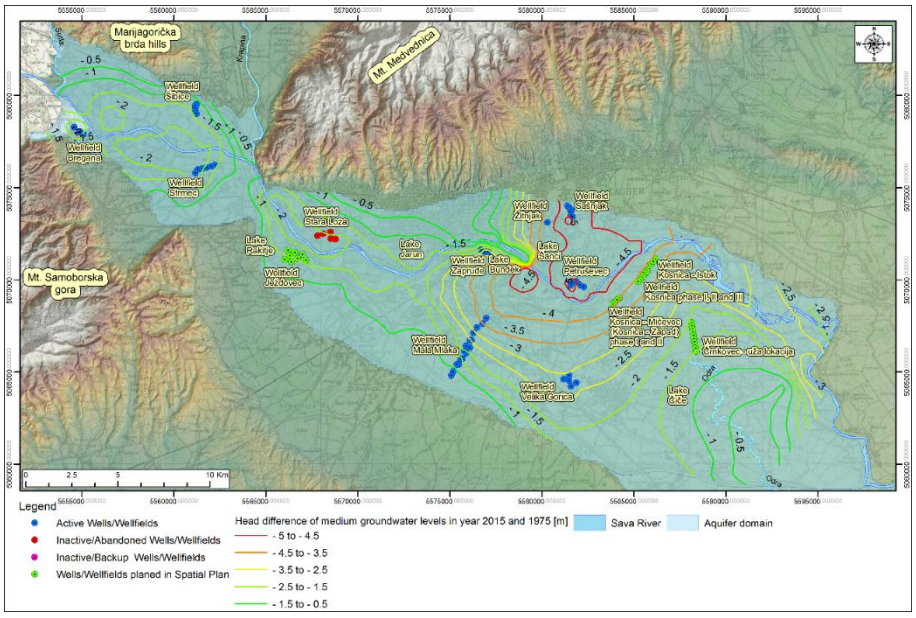

Figure 3: Isopach map of ground water level decline from the seventies of the twentieth century until year 2015

Code of abstract: T1.1.13
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.1. Groundwater heritage and trends in water levels, flows and quality

Historical and Future Trends of Groundwater Levels – 30-year Forecast for Zagreb and Samobor-Zaprešić Aquifers, Croatia

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KEY WORDS time series, groundwater level, trend, water supply

ABSTRACT

Historical trends of groundwater levels were analysed for Zagreb and Samobor-Zaprešić aquifers, Croatia. Trend analysis was conducted on 41 observation wells of Zagreb aquifer and 19 observation wells of Samobor-Zaprešić aquifer, as shown on Fig. 1. On the area of Samobor-Zaprešić aquifer groundwater level time series were analysed for entire period of monitoring, i.e. from 1967 to 2015. Due to construction of weir TE-TO on the Sava river (last major reconstruction occurred in the late 1993), which affected the aquifer recharge/discharge processes, groundwater level time series on the area of Zagreb aquifer were analysed from 1994 to 2015. Calculated trends were extrapolated for the period of next 30 years, i.e. up to year 2045, and can be considered as probable if river Sava is not regulated in future.

Continuous decline of groundwater levels cause decrease in aquifer groundwater reserves, which are defined as strategic resource of groundwater in Croatia within the Croatian Waters' Water Management Strategy, the main document for water management in Croatia. According to this document, water reserves are the primary issue of the national sovereignty and interests. Therefore, stopping of negative trend and possible raising of groundwater levels would be in line with the Croatian Water Management Strategy as well as with the EU Water Framework Directive, but also responsible from the aspect of strategic value of ground water as a vital resource whose value will surely raise in future both in local and global scale.

a	-0.000132314		
b	109.3550569		
	Lower 95% prediction	Trendline	Upper 95% prediction
HEAD 31.12.2015. (m a.s.l.)	102.33	103.75	105.16
HEAD 31.12.2025. (m a.s.l.)	101.85	103.27	104.68
HEAD 31.12.2035. (m a.s.l.)	101.37	102.78	104.20
HEAD 31.12.2045. (m a.s.l.)	100.88	102.30	103.72
P-value (0.05)	2.7847E-292	Trend is statistically significant.	

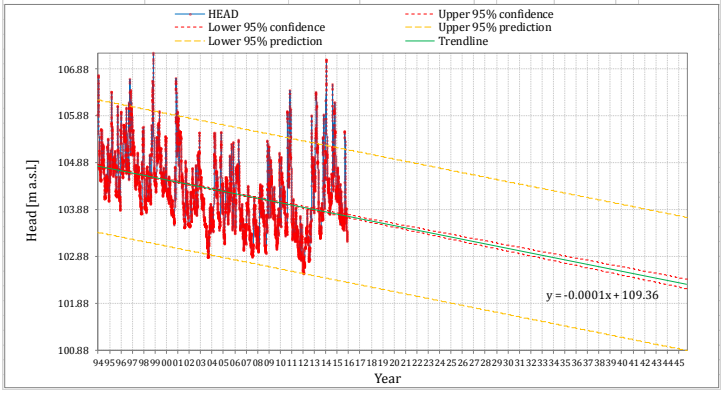

Figure 1 Example of trend analysis – Observation well 658

Code of abstract: T1.2.1
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

Numerical groundwater flow and geochemical modeling for basin-scale hydrogeologic analysis

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KEY WORDS Groundwater flow systems, numerical modelling, multivariate analysis, geochemical modelling

ABSTRACT
Regional hydrogeologic analysis requires basin-scale characterization of the groundwater flow pattern and provides a hydrogeologic framework for water resources management and to analyze geologic and geochemical process. We explore an approach based on groundwater cross-sectional numerical analysis of steady-state groundwater flow to characterize the flow pattern in a basin, graphical analysis using Stiff diagrams, principal component and cluster analyses of chemical data to identify and postulate geochemical processes and equilibrium geochemical modeling to compute saturation indexes. We aim to illustrate how groundwater flow modeling and multivariate statistical analysis can add value to the geochemical analysis using traditional techniques to develop a hydrogeologic conceptual model. To illustrate this approach we analyze the hydrogeological system in the basin of the Amacuzac River in Central Mexico. The system is composed by aquifers and aquitards both in granular, fractured and karstic rocks in a spatially variable heterogeneous manner. The hydrogeologic units were represented in three 60 to 90 km long sections parallel to the regional groundwater flow. Steady-state cross-section numerical simulations were conducted to represent the groundwater flow system through the basin and estimate bulk hydraulic conductivity values, recharge rates and residence times. In addition, forty-five water locations (springs, groundwater wells and rivers) were sampled throughout the basin for chemical analysis of major ions. The joint analysis of the modeled gravity-driven groundwater flow system and the geochemical data allowed identifying the main geochemical processes of groundwater in the basin. Recharge water in the volcanic and volcano-sedimentary aquifers increases the concentration of HCO_3^-, Mg^{2+} and Ca^{2+} from dissolution of plagioclase and olivine. Deeper groundwater flow encounters carbonate rocks, under closed CO_2 conditions, and dissolves calcite and dolomite. When groundwater encounters gypsum lenses in the shallow Balsas Group or the deeper Huitzuco anhydrite, gypsum dissolution produces proportional increased concentration of Ca^{2+} and SO_4^{2-}. These geochemical trends are consistent with the principal component and cluster analyses.

Code of abstract: T1.2.2
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

Assessing the impact of climate change on groundwater resources using a coupled irrigation system/groundwater numerical model: a case study in Lodi province (Italy)

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KEY WORDS - irrigation systems, surface/groundwater interaction, MODFLOW, climate change, groundwater resource assessment

ABSTRACT

The projected changing climate in the coming decades is expected to greatly influence water resources availability and to shape the distribution of various hydrological regimes. This phenomenon is expected to be particularly alarming in the Mediterranean region, specifically south of the Alps where irrigated agricultural systems are sensitive to the changing water availability. Under warmer climate, crops growth would consume more water to sustain the evapotranspiration during the growing seasons and future increase of drought periods, projected by climatic models, will further exacerbate such situations. In this context, the importance of groundwater resource would become more vital as it can serve as a complement water supply to confront emergent drought conditions. Appropriate groundwater management is a crucial part of the response to climate change effects. In this work, we focus on the study of surface/groundwater interactions under the influence of irrigation. A numerical irrigation system model (IDRAGRA) was used to estimate groundwater recharge in an irrigation district (Consorzio Muzza Bassa Lodigiana). The estimated recharge was then applied to a pilot groundwater flow model (MODFLOW2000), extracted from Ticino-Adda Basin regional groundwater model and focused on the northern Lodi province. The hydrogeological properties were first calibrated via steady-state simulation, and then further tested in a transient model with monthly varying recharge values for the period 2003-2013. Projection of meteorological data for the period 2071-2100 were obtained by downscaling Regional Climate Model results as input data for IDRAGRA to assess future groundwater recharge. These data were then applied to the groundwater model to estimate change in groundwater availability. Results provide a basis for the implementation of groundwater resource management policies in climate change scenarios, and for the realization of mitigation techniques to tackle global warming impact on agricultural systems.

Code of abstract: T1.2.3
Type of presentation: Oral presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

The Impact of the Last Glaciation on Groundwater Flow in the northern Baltic Artesian Basin (BAB): A Numerical Study.

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KEY WORDS: groundwater modeling, Baltic Artesian Basin (BAB), paleo-recharge, glaciations

ABSTRACT
Several evidences of subglacial recharge of meltwater are found in groundwater flow systems that were overridden by ice-sheets during past glaciations, in North America and in northern Europe. In the northern Baltic Artesian Basin (BAB), evidences of subglacial recharge include the most negative values of $\delta^{18}O$ ever measured in groundwater in Europe (c. -22‰), as well as low salinity, high excess air and cold recharge temperatures inferred from noble gases. ^{14}C dating indicates ages ranging from 30 to 19 ky BP. Those geochemical and isotopic evidences suggest that subglacial recharge took place during the Last Glacial Maximum (LGM), during which the entire region was recovered beneath the Fennoscandian ice-sheet.

To test this hypothesis of recharge, two cross-sectional models were built crossing the northern BAB along a NW-SE direction. Groundwater flow and $\delta^{18}O$ transport were simulated from the beginning of the LGM until present-day. $\delta^{18}O$ was used as a tracer of initial pre-LGM groundwater, glacial meltwater, and modern recharge. Subglacial recharge was represented numerically in a very simple way, which is in contrast with most recent studies. To account for the uncertainty related to the hydraulic properties and to the numerical representation of subglacial recharge, several sets of hydraulic properties and scenarios of subglacial recharge were tested, accounting for a few thousands simulations.

Many simulations provide a satisfying fit between the observed and the computed values of $\delta^{18}O$, which means that subglacial recharge is a likely mechanism to explain the present-day distribution of $\delta^{18}O$ in groundwater in the northern BAB. Simulations show that meltwater entirely recharged the shallow part of the basin. After the retreat of the Fennoscandian ice-sheet, meltwater was preserved in confined aquifers and flushed away elsewhere by modern recharge. Large volumes of meltwater were also probably preserved beneath the Baltic Sea. Furthermore, these simulations show that simplifying the numerical representation of subglacial recharge can be a good strategy, as it succeeds to reproduce field data while providing results that can be interpreted more easily. It offers an interesting perspective for future hydrogeological models of subglacial recharge.

Code of abstract: T1.2.4
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

Effects of hydrological extremes and climate change on surface water – groundwater interaction: Example of the Tihany Peninsula, Hungary

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KEY WORDS surface water – groundwater interaction, climate change, numerical simulation, Tihany Peninsula

ABSTRACT
Climate variability and change directly influence groundwater systems through changes in precipitation, evapotranspiration, and therefore recharge. Relative changes in either groundwater or surface water levels can modify the interaction between groundwater and surface water, which can directly affect wetlands and other groundwater-dependent ecosystems. According to our current knowledge, local flow systems are most affected by climate change relative to regional flow systems.
Wetlands in the Tihany Peninsula, Hungary, are hydraulically connected via groundwater with the surrounding Lake Balaton. These wetlands can be characterised by different groundwater-dependent ecosystems due to their different hydraulic positions. Preserving the environment and maintaining biodiversity is an important issue in this Natura 2000 area, however climatic change is expected to have an impact on each ecosystem by decreasing or even eliminating surface water.
The goal of this study is to estimate the possible effects of hydrological extremes on surface water – groundwater interaction via the example of the Tihany Peninsula, as well as to evaluate the hydrological sensitivity of the wetlands to predicted climate change and its potential consequences on the groundwater-dependent ecosystems from a hydrogeological point of view. Based on regional climate change modelling experiments for Hungary, the annual precipitation in this region is likely to decrease by about 20% by the end of the century, moreover significant increases in winter precipitation and significant decreases in summer precipitation are projected. Annual mean temperatures are also expected to increase, as is the probability of droughts.
Changes in groundwater recharge and water levels, as well as the potential modification of interactions between groundwater and surface water due to changes in climatic conditions have not yet been predicted for the area. Using numerical simulations based on observed hydraulic extremes and the predicted change in recharge, future expected water levels and changes in interaction between the wetlands have been evaluated.
The research is supported by the New National Excellence Program of The Ministry of Human Capacities.

Code of abstract: T1.2.5
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

Experimental case study to evaluate MAR efficiency using hydraulic tests in a fractured aquifer at Sangju, South Korea

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KEY WORDS - MAR, hydraulic test, tracer test, Trac, fractured aquifer

ABSTRACT
Hydraulic tests including tracer tests were performed to evaluate MAR efficiency of single-well ASR (Aquifer storage and recovery) and dual well ASTR (Aquifer storage, transfer and recovery) method in a fractured aquifer at Sangju, South Korea. Single-well tracer tests and step injection test were performed to evaluate the feasibility of ASR type artificial recharge at the well SPW-1. The injection capacity is estimated to be 5.66 m3/d from the result of step injection test in SPW-1. Graph of the longitudinal dispersity and average linear velocity along with aquifer thickness and effective porosity were suggested and those are estimated to be 2.75mm and 8.74x10-6 m/s, respectively, under the assumption of 30 m for aquifer thickness and 0.1 for effective porosity. Based on these result, the evaluated annual artificial recharge capacity is 2,066 m3 and the residence time in 1 km radial distance is 1,324 days. Radial convergent tracer test at SPW-2 and step injection test at SOB-2 were performed to evaluate the feasibility of ASTR type artificial recharge. The maximum injection capacity was estimated to be 24.6 m3/d under condition of groundwater table maintaining 30 cm below the surface. The average linear velocity was estimated to be 1.64x10-4 ~ 1.83x10-4 m/s from the analysis of tracer tests using momentum method and Trac, a curve fitting program. Based on these result, the evaluated annual artificial recharge capacity is 8,979 m3 and the residence time in 1 km radial distance is 63~71 days.

Acknowledgement: This work was supported by the Basic Research Project (17-3411) of the Korea Institute of Geoscience and Mineral Resources (KIGAM) funded by the Ministry of Science, ICT and Future Planning of Korea

Code of abstract: T1.2.6
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

The influence of long-term hydrological droughts on groundwater chemistry on river bank filtration site

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KEY WORDS: groundwater contamination, river bank filtration, hydrological drought, water quality

ABSTRACT
The long-term hydrological droughts determines conditions of the well-fields recharge and activate the unfavorable hydrogeochemical processes that influence groundwater chemistry (oxidation of sulphides and organic matter). During long-term hydrological droughts the accumulation of contaminants in soil and aeration zone occur because of relative low effective infiltration. These contaminants are moved after long-term droughts and deteriorate both: surface water and groundwater chemistry. The study presents changes of groundwater chemistry on Krajkowo well-field (Central Wielkopolska, Poland) where wells are recharged by water from Warta river after bank filtration process. After long-term hydrologic drought the increase of nitrates concentration was observed as the reason of cumulative effect of dry period. The expansion of the deep regional cone of depression activates the oxidation of sulphides and organic matter and caused increase of iron, manganese and sulphates concentrations as well as increase of total hardness. As the results of this work the methodological guidelines was formulated for groundwater monitoring to predict groundwater chemistry changes during and after long-term hydrological droughts. The guidelines for well-field operating during hydrological drought was also articulated.
This work was completed with support from the AquaNES project. The AquaNES project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 689450.

Code of abstract: T1.2.7
Type of presentation: Poster presentation
Topic: T1. Groundwater Heritage – Passing Benefits to Current and Future Generations
Session: T1.2. Groundwater management and energy source development in a changing climate

Long term chronicles of water physico-chemistry to assess human pressures and climate changes (AUVERWATCH PROJECT)

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KEY WORDS - Long term chronicles, water bodies, chemistry, pharmaceuticals, human pressures and climate changes

ABSTRACT

Pressures on water resources are becoming stronger and stronger, mainly because of the human activities - in particular the urbanization, the population growth, the increase in the standard of living, the increasing competition for water resources and pollution. Furthermore, climate change and the variations of the natural conditions contribute to aggravate these pressures. In this context, the major stake is to reach a management of the water cycle in compliance with the requirements of a sustainable development. A particular attention should be paid to the questions of temporal scale as the hydrology of the long chronicles is only able to take into account the cumulative effects of pollutants, and to integrate the climatic variations on the long term. AUVER-WATCH project is dedicated to the long-term monitoring of hydrodynamical and hydrochemical parameters, including water isotopes and organic micropollutants such as phytosanitaries and pharmaceuticals, on the major water bodies (rainfall, river and groundwater) of the Auvergne region. Nine points have been sampled since 2010 and analysed for 100 to 500 physico-chemical parameters. Seasonal variations of the water chemistry, in relation with water flow and land use occupations variability, have been highlighted. On the long term, alluvial aquifer present stable concentrations in phytosanitaries while pharmaceuticals increase both in concentrations and in the number of detected molecules. Increase in [HCO_3^-] and decrease in [SO_4^-] in the non-pumped part of the aquifer should be correlated to an upstream modification of agricultural land use. Volcanic and thermomineral springs do not show any evolution. These observations will be pursued till 2024 and accompanied by experimentations dealing with the processes occurring at the river/alluvial system interface, implying research teams of the National Observation System H+ (http://hplus.ore.fr/) and the Research Infrastructure OZCAR (http://www.insu.cnrs.fr/node/5680)

Code of abstract: T2.1.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Concept of regional groundwater flow as a tool in the delineation of groundwater bodies in accordance with the Water Framwork Directive

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KEY WORDS regional groundwater flow, intermediate groundwater flow, local groundwater flow, delineation of groundwater bodies, groundwater balance

ABSTRACT
With the implementation of Water Framework Directive (WFD) members of European Community implemented water bodies as a management concept for the establishing good status of their waters. The concept of groundwater bodies implemented in WFD helps to improve groundwater management practices and helps to direct various measures into proper direction. Concept of groundwater bodies is management tool based on the natural characteristics of the aquifers as well as administrative requirements. Existing practice has shown that in some cases revision of the already defined groundwater bodies is needed. New revision is the consequence of newly available data and management experiences gained on present delineation. In the paper we are investigating concept of regional groundwater flow concept (sensu Toth) as a possible conceptual model for the revisited delineation of groundwater bodies. Analysis and concepts are illustrated for the groundwater bodies delineation in Slovenia.

Code of abstract: T2.1.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Determination of minimum distance between production and injection wells in highly used porous geothermal reservoirs

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KEY WORDS - geothermal energy, doublets, deviated well, numerical model, Pannonian Basin

ABSTRACT
The movement of groundwater is influenced both naturally, by geological processes, and artificially, by human activities. The geological processes modify the gravity-driven flow space, disrupting the equilibrium of sedimentary basins. Adapting to the changes the system tries to reach a new equilibrium suitable for the modifying force. Human activities, on the other hand, induce changes to groundwater that occur at a faster pace and more abruptly than the natural processes, allowing for less time and fewer ways for the reservoir to recover.
The Southern Great Plain, Hungary's most potent thermal water reservoir provides heat and water supply to dozens of spas, cascaded heating systems and agricultural operations from such a disturbed sedimentary basin, whose exploitation continues to increase.
In 2016 the local government of Szeged initiated the integration of renewables into district heating. A team of professionals from the University of Szeged outlined a 5-year roadmap for the introduction of geothermal into 4 of the company's 23 heating circuits, and started the preparation activities of the development. With a 5°C/100m geothermal gradient, 100 mW/m^2 average heat flow, and a 1,500m thick Upper-Pannonian aquifer the project seems to be low-risk.
However the recent increase in the number of thermal and hydrocarbon wells in Szeged brings up the issue of interference between the wells. Injected water may cause significant cooling in nearby production wells, while an excessive distance between doublets may result in the decrease of the pressure to be ensured by injection. Therefore, it is vital to assess the reservoir's hydrogeological parameters to determine the optimum distance between the wells in urban areas.
The already existing knowledge of the reservoir's properties are complemented with pump and pulsation test results. This synthesised information creates a basis for hydrodynamic modeling, which visualises the interference between the already operating and the planned new wells. Based on this recommendations are made for sustainable operation, well placement and reservoir management.
This study is financially supported by the GINOP-2.1.1-15-2016-00970 programme.

Code of abstract: T2.1.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea

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KEY WORDS Baltic Sea, nutrient reduction, lagtime

ABSTRACT

Limitation of the ongoing eutrophication of the Baltic Sea requires substantial reductions of nutrient loads (N and P) reaching the coastal zones of this important marine ecosystem. The BONUS Soils2Sea project is elaborating the concept for spatially differentiated regulations to support effective reduction of nutrient loadings originating from agricultural activities. The effectiveness of spatially differentiated measures could be evaluated in two aspects: (i) reduction of nutrient loads to the Baltic Sea via groundwater and stream pathways; (ii) response time of marine ecosystem to nutrient load reduction.

Transport of conservative contaminants through groundwater systems (e.g. nitrate under oxidized conditions) is significantly delayed when compared to movement of those contaminants through surface water compartments. Characteristic time scales of groundwater movement can easily reach tens or hundreds of years. This results in large delays in transport of contaminants through the subsurface. Contaminant transport in the subsurface, when compared to transport through surface and near-surface runoff (drainage), is necessarily characterized by significant delay (lagtime), which can be further separated into two components: (i) the delay associated with travel time of water and contaminants through the unsaturated zone, and (ii) the delay linked to timescales of groundwater flow, from the recharge area down to the discharge zone (river). Thus, total travel time of water through unsaturated and saturated zones can be considered a quantitative measure of the lagtime of contaminants.

Lagtime of nutrients in the unsaturated zone on the territory of Poland was assessed using the concept of mean residence time of water (MRT) in this zone, whereas the time spent in the saturated zone was approximated by the travel time (T_{sat}) of water flowing along the local hydraulic gradient to the closest river. The total lagtime (MTR + T_{sat}) for the Polish part of the Baltic Sea catchment is in the order of 25 years (range from 10 to 60 years corresponding to one standard deviation).Spatial distribution of lagtime values On the Polish territory allows to identify agricultural regions for which implementation of differentiated regulations will result in fastest response of the system in terms of N and P loads in the rivers discharging to the sea.

Acknowledgements. The work was supported by the BONUS project (Soils2Sea) and the statutory funds of the AGH University of Science and Technology (projects No.11.11.140.797 and 11.11.220.01).

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Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

The Groundwater trends – the Human impacts vs. Climate Change

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KEY WORDS - Groundwater level trends, measurements, aquifer, land use, groundwater abstraction

ABSTRACT

The data analysis confirms that the aquifers of Iška fan are very sensitive to extreme weather conditions as well as to human impacts. The water field Brest is in production since 1981, from where groundwater is abstracted from different depths through a series of 10 shallow wells. Pesticides and other contaminants present in the groundwater caused a change in the pumping regime. The groundwater abstraction from different aquifers influences the groundwater gradient which can cause the pollutant transport from the upper Holocene aquifer to the underlying Pleistocene upper and lower aquifers.

The sensitivity of the aquifers of Iška fan is evident also from groundwater level fluctuation analysis. After the events in September 2010 (floods, disappearance of river Iška, earthquake) we can see greater amplitude in groundwater level fluctuation. There are higher maximum and lower minimum values despite the yearly amount of precipitation being very similar to those from the previous years. From 2010, during dry periods, we can observe very low groundwater level in the shallow wells in the western part of water filed Brest (VD Brest1, VD Brest 2, VD Brest 3 and VD Brest 4).

In the paper we'll analyse the more than 30 years long data set of groundwater level measurements. We'll compare the groundwater trends to Iška river discharge in precipitation in the same period. And on the other hand we'll analyse the impact of groundwater extraction and land use changes on groundwater recharge.

Code of abstract: T2.1.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Socio-hydrogeological assessment of nitrate contamination in areas of intensive agricultural use: the case of the Lombardy Plain (North Italy)

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KEY WORDS Socio-hydrogeology, aquifer pollution, isotopes, public engagement, stakeholder analysis

ABSTRACT
Diffuse contamination of groundwater associated to human activities represents a major threat to the long-term sustainability of water resources worldwide. Indeed, despite the advances in scientific knowledge and the increasing regulations for groundwater protection, in many highly impacted areas mitigation actions do not seem to be effective and groundwater contamination still represents a major environmental concern. Due to the intensive agriculture, industries and human settlements, the Lombardy plain has a strategic role in the Italian economy, while generated and transported N loads highly contribute to impact on the Mediterranean ecosystems and to the increase in groundwater purification costs. The INTEGRON project, funded by the CARIPLO Foundation (Grant number: 2015-0263), aims at evaluating the role of groundwater as a temporary or permanent sink or as a source in nutrient mass balances at the catchment scale in two key sub-basins of Po River, the Adda and the Ticino. Taking in account the multiple criticalities of the area a preliminary socio-hydrogeological assessment was performed coupling hydrogeological and social analysis (namely social network analysis and public engagement) in an investigation targeted at constraining nitrate contamination sources in a region of high agricultural use.
The analysis of isotopes and time series show an uneven distribution of nitrates in groundwater, not fully matched to any of the civil, industrial and agricultural sources and a persistence of significant quantities of nitrates in groundwater, despite the implementation of the Nitrates Directive (European Commission, 1991). The stakeholder analysis performed, using the Net Map toolbox, with different target groups of key informants (authorities, farmers, researchers and trade unions) permitted a deeper comprehension of the complexity of the stakeholders' network, while also highlighting the power relations and conflicts among the different groups. The complexity of the networks and the emerging multiple perceptions confirm the need to enforce a holistic approach in groundwater investigations.

Code of abstract: T2.1.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Drinking water protection zones in Adriatic and Ionian region

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KEY WORDS - groundwater, surface water, artificial water bodies, drinking water, trans-boundary water resources

ABSTRACT
Drinking water protection zones are crucial measures for the protection of the recharge and contributing areas of drinking water resources. They are implemented as spatially zoned areas where prohibitions, limitations and measures are emplaced. Their design principles are based on the natural characteristics of the aquifers, surface and artificial bodies as well as on the technical characteristics of the capturing facilities. Protection practices are related also to the state and regional legislation. In the frame of DRINK ADRIA project financed by IPA Adriatic Cross-Border Cooperation Programme we have analysed current protection practices of the drinking water resources in the eight states of Adriatic and Ionian area; Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, Slovenia and Serbia. In the region several cross-border drinking resources are present and practically no practice for such drinking resources protection is present. Analysis was based on the expert knowledge, extensive questionnaires and direct communication between members of the team and other experts. Comparison of the criteria for the establishing protection zones, legislation and implementation practices, and design practices were done. Based on this comparative analysis we have proposed guidelines for the protection of cross-border drinking water resources based on the principle of acceptable compatibility. The principle supposes if similar protection measures according to the national legislation are implemented in the both sides of the state border dividing the recharge area of cross-border drinking water resource this is acceptable. According to our knowledge this is first ever systematic and comparative study of drinking water protection practices among different states in the region as well as probably in the wider area.

Code of abstract: T2.1.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Groundwater status assessment of the Dinaric karst area of Croatia

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KEY WORDS - Dinaric karst aquifers; Groundwater body; Groundwater body status; Groundwater body risk

ABSTRACT
Croatia belongs to the group of the Mediterranean countries with large karst catchment areas. Recharge zones of these aquifers are in mountainous area where is the watershed between the Danube River Basin and the Adriatic Sea Basin. Discharge zones of Dinaric karst area are springs which form rivers flowing to Danube on the north, and springs which form rivers flowing to Adriatic Sea and coastal springs at the south. This typical carbonate karst area covers almost 50 % of the national territory of Croatia. The importance of Dinaric karst aquifers for Croatia is priceless for today's functioning of water supply systems, which includes the entire coastal touristic region and some of the towns in the inland. Also, karstic aquifers are the strategic reserves of drinking water for the future development of the Croatia.
Because of the specificity of karst aquifers, in Croatia is developed a specific methodology of assessment of quality and quantity of karst aquifers that will be presented in this article.
Karst area in Croatia is divided in 17 groundwater bodies (GWB) on which are performed quantity and quality status assessment. By assessing the chemical status two GWBs are declared as "in bad status" and are in the category “at risk”. These are the southern part of the Istrian peninsula and the wider area of Zadar city in Dalmatia. In southern part of Istria the problem is due to increased concentrations of nitrates and the problem in wider area of Zadar city is due to occasional saltwater intrusion to the aquifer. Assessing the quantitative status only wider area of Zadar city is declared as "in bad status" and “in risk” because of the occasional saltwater intrusion. Instead of that aquifer, the risk assessment additionally declared southern Istria also in the category "at risk" because of the possible saltwater intrusion. All other GWBs in karstic area in Croatia are in “good status” and “not in risk”.
On these two GWBs the further characterization is performed with prescription of protection measures and operational monitoring system. We hope that these measures will provide improvement of the groundwater status by the end of the next planning cycle (next RBMP - 2021).

Code of abstract: T2.1.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Sustainable Management of Groundwater Resources in the Context of Climate Change Impact Assessment - Examples from Croatian Karst areas

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KEY WORDS karst springs, climate change, water supply, water balance, Croatia

ABSTRACT

Karst springs are characterized by a pronounced variability in flow and large sensitivity to the occurrence of long dry periods when their yield assumes extremely low values. This is especially important if these water resources are used for water supply. In this case the sustainable use of these water resources implies the need to estimate possible changes in water regime due to the impact of climate change. This kind of modelling and analyses of water balance was conducted for two pilot areas in the karstic part of Croatia within the DRINKADRIA project. The first pilot area is the river Mirna basin, where water supply sources Gradole, Sv. Ivan and Bulaž are analysed. Source Gradole is used for the water supply of a part of Istrian Region but also, in summer time, for the water supply of the Slovenian coast. The second pilot area is the water supply source Prud in river Neretva catchment. Spring Prud is located in Croatia, but only few hundred meters from the border with Bosnia and Herzegovina where almost all of its catchment is located. The paper presents the climate change impact assessment on these spring, as well as the overview of the most important results obtained. Three climate models (RegCM3, Aladin and Promes) were used for modelling the temperature and precipitation changes in the future (2021-2050) on pilot areas. Although there are some differences in their results (Promes climate model estimates the highest changes), all three models predict the air temperature increase and stagnation of precipitations. This causes the significant decrease in water balance of analysed springs that was estimated with hydrologic modelling. This decrease is obvious on the level of mean annual flow (up to 35%, for Promes input data), and even more emphasized on the level of minimum mean monthly flow (up to 60%, for Promes input data). Estimated results, as well as present needs for water in pilot areas emphasize the need to find additional measures to adapt to climate change, and find alternative solutions for optimal water management of analysed karst springs.
Such modelling of water balance provides a prerequisite for the sustainable management of water resources in the possible upcoming situations, the occurrence of critical hydrological conditions. This model can be applied for similar assessments even in other localities.

Code of abstract: T2.1.9
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Model solution of artificial recharge in shallow hard rock aquifer in Czech Republic

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KEY WORDS artificial recharge; groundwater, hard rock

ABSTRACT
The effect of climate change and long term drought on water resources is becoming an important water management issue for many regions worldwide, including Czech Republic in Central Europe. A major part of the country is formed by magmatic and metamorphic crystalline bedrock, where groundwater occurs in shallow aquifer in permeable fissures and weathered zones. Locally, such aquifer may provide an important water resource, but due to low accumulation capacity, it can be very vulnerable to drought.
Our study proposes a method for mitigation of negative effect of drought in areas with crystaline bedrock. It uses modeling tools to assess the efficiency of different technologies of artificial recharge in order to improve water budged of a shallow hard-rock aquifer. A combination of hydrologic and hydraulic numerical models was prepared for an experimental catchment located in Šumava Mts. in Southern Bohemia, where a complex long-term monitoring system records meteorological data, surface water discharges and groundwater levels. The first step of the assessment was hydrological modelling, which analysed runoff components and resulted in time series of natural recharge of the aquifer. This data was used as a crucial input to a hydraulic model, which was first calibrated to measured groundwater levels and then used for simulation of several hypothetic conditions, including long term drought and different means of artificial recharge in the upper part of the experimental catchment. The results of the study reveal the sensitivity of the shallow hard rock aquifer to drought and artificial recharge methods and quantify its effect on the water budget. The outcome can be generalised to other areas with similar conditions and can serve as a material for creating new strategies of adaptation to drought conditions.
The research leading to these results was financially supported by GA UK (Charles University Grant Agency).

Code of abstract: T2.1.10
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.1. Sustainable management of groundwater resources in Central Europe (CE) – 3rd IAH CE

Evaluation of Water Resources Carrying Capacity of Gonghe Basin—Based on fuzzy comprehensive evaluation method

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KEY WORDS - Gonghe Basin; water resources carrying capacity; fuzzy comprehensive evaluation method

ABSTRACT
Gonghe Basin belongs to the arid and semi-arid climatic zone, the water resources is relatively scarce, desertification is serious, it is urgent to find out the water resources carrying capacity. Using fuzzy comprehensive evaluation method, assessment on water resources carrying capacity in Gonghe Basin: the water resources carrying capacity of Gonghe county is less, of Guinan county and Chaka town of Wulan county is greater; the water resources of Gonghe Basin could carry cultivated land and grassland 652.6 and 2368.6 thousand acres respectively in 2020, the water resources of Gonghe Basin could carry cultivated land and grassland 948.2and2247.6 thousand acres respectively in 2030.

Code of abstract: T2.2.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

A multi-decadal financial assessment of groundwater services for low-income households in rural Kenya

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KEY WORDS handpumps, Kenya, financial sustainability, Sustainable Development Goals

ABSTRACT
Sustainable financing of groundwater-based drinking water supplies in rural Africa poses one of the biggest obstacles to the global Sustainable Development Goal of safely managed water for all by 2030. Hand-pumped groundwater is the chief mode of supplying safe drinking water to rural populations in Africa. Yet around one in three systems is non-functional in part due to a failure of users to pay the costs of ongoing operation and maintenance. Limited empirical evidence identify which factors determine rural communities' capacity to collect revenue from users, and the implications this has for the operational sustainability of services and the water source choices of users. We present findings from a unique study that assesses community-based financing of groundwater services in Kwale (Kenya), the location for one of the first ever large-scale programmes involving handpump-equipped boreholes in rural Africa. The study draws on longitudinal financial records kept by 100 water user groups over three decades, coupled with hydrogeological, community, and household-level data collected from over 500 waterpoints and 3,000 households. We find that among those communities collecting fees on a monthly basis, around one in four households fails to pay in the long-run. Multivariable regression analysis reveals that waterpoints that (i) are situated close to households, (ii) draw on groundwater with a pH above 6.5, (iii) produce palatable water, and (iv) support productive water use activities have significantly higher levels of payment compliance. Payment levels are also strongly related to rainfall patterns, suggestive of complex and dynamic decisions about water source preferences. Those communities charging water users on a pay-as-you-fetch volumetric basis generate the highest levels of revenue, and this translates into significantly shorter breakdown durations. Yet this revenue collection approach is also associated with a higher proportion of households using unsafe water sources, a pattern that occurs across all wealth strata. We conclude that this points to a tension between groundwater service goals of financial sustainability and inclusive access, a conundrum that must be addressed if safe water for all is to become a reality in rural Africa.

Code of abstract: T2.2.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Addressing seasonal flooding and groundwater depletion issues through innovations in MAR: Pilot tests and modelling to evaluate technical feasibility in the Ramganga basin, India

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KEY WORDS Managed Aquifer Recharge, floods, droughts, groundwater depletion, Ganges basin

ABSTRACT

New solutions are needed to address the socioeconomic impacts of floods and droughts globally, and particularly across the developing world. One such solution applied the basin scale involves storing excess wet-season flows in depleted aquifers, thus preventing flooding and providing additional groundwater for intensifying irrigated agriculture and enhancing livelihoods. This solution we have aptly named "*underground taming of floods for irrigation*" (UTFI).

Thorough planning and staging are needed when progressing from design to implementation applying UTFI to ensure risks are addressed. To gain a general idea on the prospects for UTFI in the Ganges Basin, a composite-index suitability map was developed based on drainage density, flood frequency, flood mortality and distribution, extreme rainfall events, landuse, population density, geology, slope, soil, groundwater level, aquifer transmissivity and economic loss due to floods. This shows that suitable conditions for UTFI are found across much of the Gangetic Plains. At one such area in western Uttar Pradesh where declining groundwater levels and seasonal floods are extremely problematic a village pond was converted to a recharge system. This gravity flow system consists of 10 infiltration wells, accepting sand-filtered water from a nearby river linked via a canal. The recharge rate for the system averaged 5,700 m^3d^{-1} in the wet season of 2016. The local community perceive UTFI to be of benefit and clogging impacts to date have been manageable. Evaluations of water quality and socioeconomic aspects are underway to better reveal the performance, benefits, costs and trade-offs.

Semi-coupled surface hydrology (SWAT), groundwater (MODFLOW) and flood inundation (HEC-RAS) models were developed for the Ramganga basin (~19,000 km^2) to understand the baseline hydrologic regime and test scenarios with distributed UTFI. Results indicated for a runoff reduction of just 20% would lead to groundwater depletion trends being reversed, baseflow enhanced and flood inundation area reduced within a decade.

The evidence generated from the piloting and modelling serves to inform different stakeholder groups and consider UTFI amongst the options when planning for climate change adaption/mitigation and disaster risk reduction in India and potentially in other regions.

Code of abstract: T2.2.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Analyzing the groundwater potential and spatiotemporal interactions with surface water in the Sand River, Mara Basin, Kenya

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KEY WORDS - Water security, Sand River, Storage potential, ERT, Hydrochemical tracers

ABSTRACT

Economic development in arid and semi-arid areas in developing countries is limited by water availability. Typical to dryland areas, surface flow in the Sand River in Southern Kenya is highly variable due to erratic and unreliable rainfall patterns. Even with surface water harvesting infrastructures such as water pans, high rates of evaporation cause rapid water losses, which is unsustainable in such a water scarce region. Groundwater is an alternative source for livelihood improvement in a region that is characterized by a high level of poverty. However, the high water demand for domestic use, small-scale irrigation and a particularly high livestock population cannot be met by expensive infrastructures for extracting deep groundwater. Where the presence of deep groundwater is poorly known and highly irregular, the ephemeral Sand River constitutes a potential alternative groundwater source in the region. This water is present in the sands deposited by the river that store water, which in principle can be exploited to ensure availability all year round, and is currently used through traditional techniques such as sand scooping. Notwithstanding, very little is known about these alluvial corridors. The present work aims to study the storage potential, groundwater dynamics and interactions with surface water flows in the Sand River. Various techniques were adopted, including geophysics (ERT) and probing, hydraulic conductivity and effective porosity measurements, surface flow and groundwater level measurements at varying timescales, as well as hydrochemical and isotopic tracing of groundwater and surface water. Together they provide an interesting insight into the near-surface hydrological interactions and dynamics, as well as the total storage capacity of the system. Surveys and interviews were conducted to assess the water demand versus current availability and use in the Sand River region. The work allowed increasing the understanding of the dynamics and potential use of sand rivers, also found in many other parts of the world, including well documented cases in Kenya, Zimbabwe and Ethiopia. The use of such sand rivers for the alleviation of poverty and increase of water and food security needs to be seriously considered, but at the same time impacts on dependent ecosystems need to be analysed and minimised.

Code of abstract: T2.2.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Characterization of shallow aquifers in Guinea Bissau to support the promotion of manual drilling at country level

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KEY WORDS - manual drilling, low cost water supply, shallow aquifers

ABSTRACT
In Guinea Bissau there is still a large gap in safe water supply between urban and rural areas. Most of the small villages are not included in mechanized drilling programs because of the high cost relative to the population size. For this reason other low cost options could represent a valid solution. DRGH (Direccao Geral Recursos Hidricos) and UNICEF promoted in 2016 a preliminary study in Guinea Bissau to identify those areas with suitable conditions for manual drilling (i.e. presence of thick unconsolidated shallow geological layers and limited groundwater depth). In this research the approach and tools developed in the UPGRO research program in Senegal (Fussi, 2015) were used.

The main source of information has been the existing database of water points at national level. An inventory of 4418 water points stored at DGRH and a subset of 427 existing stratigraphic logs were used. The available groundwater information is huge in Guinea Bissau, but the quality of data make them not clearly accessible and easy to manipulate.

Stratigraphic logs were processed using a manual standardized codification and a semi-automatic procedure to extract a set of hydrogeological parameters (i.e. depth of water, depth of hard rock, thickness of layers with predominant sandy texture and thickness of hard lateritic layers) which were used to estimate the feasibility (i.e. the possibility to drill a hole using manual drilling techniques and reach an exploitable saturated aquifer) and the potential (an indirect and qualitative estimation of potential yield that can be obtained) at logs position. The extrapolation of feasibility and potential for manual drilling to the whole territory was carried out identifying spatial units with similar geological and morphological characteristics through a GIS overlay of geological map and digital terrain model.

This study demonstrated the potential of hydrogeological analysis using simple methods and existing data in Africa, therefore a possible approach for low income country to support groundwater development.

Reference:
FUSSI, F. 2015 *Integration of hydrogeological investigation, remote sensing and terrain modeling for the analysis of shallow aquifers in West Africa and the identification of suitable zones for manual drilling*. PhD Thesis, University Milano Bicocca

Code of abstract: T2.2.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Comparison of multiple groundwater recharge assessment methods for a shallow aquifer: Why are the results so varied?

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KEY WORDS Groundwater recharge, citizen science, Ethiopia

ABSTRACT
Quantification of groundwater recharge is a crucial element of hydrogeological study in order to assess the potential of an aquifer. Only with knowledge of groundwater recharge rates can safe abstraction quantities be determined to prevent aquifer depletion and negative impacts on river baseflows and groundwater-fed wetlands. There are numerous alternative techniques for estimating recharge. How do we choose between them? Does it matter?

Generally, selection of a technique is dependent on data availability and, especially in less developed regions, there are often insufficient data available. This research is a rare example of having sufficient data to allow robust comparison between various methods.

The study site is Dangila *woreda* in northwest Ethiopia. The area has an average elevation of around 2000 m and a median annual rainfall of 1541 mm, ~90 % of which falls during May to October. Data collection involved several periods of fieldwork and the setup of a community-based hydrometeorological monitoring programme.

Twelve recharge estimation techniques are compared in terms of data requirement, complexity and cost. Original field data collected at the case study site were used with an empirical method (a rainfall-runoff relationship based on sites across Ethiopia), three streamflow hydrograph methods, basin water balance, chloride mass balance, water table fluctuation, rainfall infiltration breakthrough, and physically-based modelling. Two further methods, large-scale mapping and remote sensing, take recharge values from published studies for the same region. The calculated annual recharge results range from around 50 to 500 mm or 3 to 32 % of average annual precipitation. With the study area measuring under 1000 km^2 should the range be so broad? Reasons behind the discrepancies between the recharge estimates are presented.

Code of abstract: T2.2.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Exploiting our groundwater resource: choices and challenges in managing the water commons

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KEY WORDS - groundwater, resilience, communities, agency, Nigeria

ABSTRACT

Across much of Africa, domestic water supplies are increasingly dependent on groundwater reserves. This has, in part, been enabled through a significant increase in water wells, or boreholes, financed by governmental development programmes and NGOs as well as investments by water users and local businesses. As the cost of accessing groundwater reserves fall, expertise becomes more widely available and incomes rise there is a rising trend towards the private commissioning of boreholes and wells. The development of such self-supply options is also being promoted by humanitarian organisations that see this as a viable means to provide access to water for the hardest to reach and so to alleviate poverty and improve livelihoods.

This nascent shift towards a distributed and increasingly individualised water supply may have implications for the resilience of communities to future environmental shocks, which are, as yet, under-explored. Drawing on the case of Nigeria and new interdisciplinary research, this paper addresses this gap, through a specific focus on understanding the behaviour and choices of individuals and other key stakeholders which underpin this trend. It also seeks to understand the possible implications of this for the resilience of associated social and ecological systems. In doing so it considers whether the short-term goal of promoting the private development of boreholes may have unintended longer-term consequences.

Code of abstract: T2.2.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Groundwater resources for the arid North of Namibia from an inland mega-fan system

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KEY WORDS Namibia, mega-fan, aquifer, Ohangwena

ABSTRACT
The central north of Namibia is a semi-arid but relatively densely populated region. It has repeatedly experienced extensive drought periods. Population number and water demand are expected to grow, putting more stress on the already scarce water resources, much of it sourced from the Kunene River. The local aquifers, a perched (KOH-0) and a semi-confined one (KOH-1), often contain brackish water, which limits their use. At the end of the 1990s, a deep freshwater aquifer was discovered. This Ohangwena-II aquifer (KOH-2) is part of an inland mega-fan system, reaching from the Angolan highlands in the north almost to the Etosha Pan in the south of the Cuvelai-Etosha Basin (CEB).

Initially, little was known about the geological framework of the CEB and its hydrogeological boundary conditions (e.g. spatial extent, recharge area and rates, interaction with KOH-1). To overcome this, among other activities, a cored borehole was drilled to a depth of 400 m. Samples were analyzed for their geochemical and mineralogical composition, granulometry and hydraulic properties. The data trace three distinct depositional sequences. The lower Olukonda Formation (270-400 m) shows a fining-up sequence, but with distinct sedimentological heterogeneity, rendering it a poor aquifer. It is overlain by the Andoni Formation, of which the KOH-2 (170-270 m) forms the lower part. It shows a fining-up sequence but with much less pronounced heterogeneity, which qualifies it as productive aquifer. The transition between Olukonda and Andoni Formation is marked by distinct changes in geochemistry, indicating different source areas. The KOH-2 is overlain by a third sequence, containing both aquitards and aquifers (KOH-1 (80-110 m), KOH-0).

The sedimentological features of inland mega-fans strongly affect the distribution and hydraulic properties of aquifers and aquitards. This knowledge will be useful for the further exploration and sustainable development of the KOH-2.

Code of abstract: T2.2.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Integrated socio-hydrogeological approach to tackle nitrate contamination in groundwater resources. The case of Grombalia Basin (Tunisia)

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KEY WORDS Socio-hydrogeology, aquifer pollution, isotopes, public engagement, stakeholder analysis

ABSTRACT
Nitrate contamination is one of the main groundwater quality issues in several aquifers worldwide, despite the strong efforts of the international scientific community to effectively tackle this problem. The classical hydrogeological and isotopic investigations are obviously of paramount importance for the characterization of contaminant sources, but often lack of an adequate assessment of the socio-economic component of any given groundwater controversy. As a result, biased strategies could be put in place leading to an ineffective solution of the groundwater issue at stake. In this context, socio-hydrogeology was introduced as a way to go beyond the state of the art of classical hydrogeological investigations while contributing to adequately assess the cause-effect relations between groundwater and society.
An integrated investigation, including land use, hydrochemical and isotopic ($\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$) analyses, coupled to capacity building and participatory activities was carried out to correctly attribute the nitrate origin in groundwater from the Grombalia Basin (Tunisia), a region where only synthetic fertilizers have been generally identified as the main source of such pollution. Results demonstrates that the basin is characterized by nitrate concentrations exceeding the statutory limits for drinking water, in both the shallow and deep aquifers. Isotopic data indicate that, contrary to what suggested in previous studies, nitrate contamination is not only associated to agricultural practices, but also has a domestic origin, especially in the most densely populated areas. This finding could explain the reason for the continuous rise in nitrate concentrations, still observed despite the change in irrigation practices, the latter information provided by farmers during structured interviews.
The Social Network Analysis and the public participation of local actors proved to be a fundamental element for the development of the hydrogeological investigation, as it permitted to obtain relevant information to support data interpretation, and presenting explanations for otherwise unexplained social and political dynamics governing the groundwater sector.

Code of abstract: T2.2.9
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Large-scale modelling of groundwater resources: insight from the comparison of models and *in-situ* observations in Sub-Saharan Africa

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KEY WORDS in-situ observations, groundwater levels, larger-scale models, recharge, Africa

ABSTRACT
As groundwater-level monitoring networks are limited globally, there is considerable dependence on the output from Global Hydrological Models (GHMs) and Land-Surface Models (LSMs) not only to estimate groundwater recharge but also to resolve groundwater storage changes from GRACE satellite measurements. Fundamental limitations remain, however, in the ability of GHMs and LSMs to represent groundwater recharge processes and geological controls on groundwater occurrence. Very few studies, to date, have tested the robustness of terrestrial water balances including estimates of groundwater recharge simulated by LSMs and GHMs using in situ observations. Here, we report on preliminary analyses comparing groundwater recharge and subsurface runoff (*i.e.* proxy for groundwater recharge) estimated by 4 LSMs (CLM2.0/CLM4.5, NOAH, MOSAIC, VIC) and 3 GHMs (PCR-GLOBWB, WaterGAP, MATSIRO) at 1°x1° to multi-decadal records of groundwater levels from 8 countries (Benin, Burkina Faso, Ghana, Niger, South Africa, Tanzania, Uganda, Zimbabwe) and stable-isotope tracers collated from long-term IAEA stations and published sources in 7 countries (Burkina Faso, Chad, Ethiopia, Namibia, South Africa, Tanzania, Zimbabwe). Analyses reveal substantial spatial variability among GHMs and LSMs in the estimation of potential recharge and subsurface runoff, respectively. Precipitation and subsurface runoff in LSMs show non-linear (*i.e.* reflecting bias to heavy rainfall), linear, or no bivariate associations in contrast to consistently non-linear relationships noted from the comparison of stable-isotope ratios in rainfall and groundwater. GHMs also demonstrate substantial variability in computed potential recharge though greater consistency is observed in their dependence of groundwater recharge on monthly or seasonal rainfall exceeding a monthly or seasonal threshold, consistent with some piezometric records. Multi-decadal groundwater-level data reveal the prominence of indirect recharge processes in semi-arid areas (*e.g.* Niger, South Africa, Tanzania, Zimbabwe) despite their current exclusion from all but one large-scale model.

Code of abstract: T2.2.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

On the rise of pit latrines and the safeguard of groundwater in Southern Malawi

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KEY WORDS - pit latrine, groundwater contamination, Africa, sanitation, WASH

Numbers of pit latrines are rising globally in developing countries as more populations gain access to improved sanitation, particularly following the success of the Millennium Development Goal on sanitation. Pit latrines are the most common low-cost solution to sanitation problems in low-income countries – some 1.7 billion people are estimated to use them. In parallel, many developing countries with WASH programmes are also gaining improved access to drinking water, often groundwater. Typically this is via numerous low-capacity boreholes that are often close to populated areas and hence can be in proximity to expanding numbers of pit latrines. The lack of a barrier between latrine excreta and the underlying soil – groundwater resource and recognising that abstracted groundwater is often not treated, together underline the need to better understand possible connectivity between latrines and supply boreholes and the safeguard of groundwater resources. Data are presented from supply boreholes in the Mwanza Valley area in semi-arid Southern Malawi where groundwater quality indicators (microbiological, chloride and nitrate concentrations) of possible latrine pit influence are assessed in relation to surrounding pit latrine occurrence and possible controlling actors that may control the incidence of latrine-related contamination, including the statistical evaluation of lateral pit – water point distance, pit latrine density, borehole infrastructure condition and modelled borehole - groundwater capture zone nature. Overall contamination levels were found to be low with possibly some microbiological and nitrate contamination potentially attributed to pit latrines. However other sources may be responsible, for example, microbiological occurrence correlated with the absence of a protective borehole wall at ground-surface may suggest local sources and perhaps leakage of contamination around the borehole annulus. Chloride was a poor anthropogenic latrine tracers due to naturally elevated salinity sporadically present within the alluvial aquifer system. As pit latrine use was until recently quite limited in the Mwanza valley, the study area may represent a “young problem” scenario that is emergent. Importantly, the collected data hence provide a reasonable baseline against which any future influence may be monitored. Future research needs, both within the Malawian context as well as globally, are considered in conclusion.

Code of abstract: T2.2.11
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Rapid screening for pathogens in drinking water: preliminary results from a national scale survey in Malawi

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KEY WORDS - pathogens, rapid screening, drinking water quality, Malawi

ABSTRACT
Drinking water supplies contaminated with bacteria and viruses cause diarrheal diseases, which kill 1.8 million people a year. Sustainable Development Goal 6 highlights the need to address this issue. Currently, pathogen presence is commonly assessed by culturing thermotolerant coliforms (TTCs) as surrogate indicator organisms, however, this is an intensive and time-consuming laboratory process. Early studies have shown that the use of tryptophan-like fluorescence (TLF) as a real-time indicator of thermotolerant coliforms in the field is promising, through comparison with established laboratory culturing methods.

This study investigates the water quality of drinking water supplies in rural Malawi, Sub-Saharan Africa, at a national scale, employing both TLF and TTC culturing methods. A rigorous hierarchical approach to the sampling (a two stage stratified randomised design) was undertaken, to ensure a representative data set was collected. A total of 183 water sources across five districts in the dry season were sampled. In addition, a sub-set of sources were re-visited in the wet season. Results from an assessment of the variability in water quality from key sources (hand pumped boreholes and shallow wells), seasonal effects of rainfall and associated health risks will be presented, including a comparison of the TLF and TTC culturing methods alongside supporting hydrogeochemical data.

Code of abstract: T2.2.12
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Groundwater access and poverty in sub-Sharan Africa Findings of a scoping study

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KEY WORDS groundwater, poverty, Africa, rural, urban

ABSTRACT
A two-month study of the linkages between groundwater access and poverty was undertaken in the first quarter of 2017. This work was carried out in the context of the research programme UPGro (Unlocking the Potential of Groundwater for the Poor). In its first phase 15 year-long "catalyst" projects were undertaken. In its present phase UPGro consists of five consortium research projects, undertaken by about 125 researchers, working in a total of 12 countries. A Knowledge Broker team provides the function of translating, versioning and communicating the research findings to wider practitioner and decision-maker audiences. The programme is jointly funded by the UK Government's Department for International Development, its Natural Environment Research Council and its Economic and Social Research Council. The main objective of the poverty study reported here was to better understand and conceptualise the linkages between groundwater access and poverty in Africa; secondary objectives were to identify knowledge gaps to enable the development of a substantive future research programme; and to widen the research network of those interested in groundwater-poverty linkages in the region. The study enabled the research team to carry out a wide-ranging literature review, an overview analysis of the UPGro programme's own contribution, selected data analysis tasks, and an investigation specifically focused on urban groundwater. At the time of writing this abstract the study findings have yet to be synthesised and reported. However they are expected to reinforce (if only through qualitative and anecdotal data) the assumed potential of groundwater to alleviate or mitigate poverty; while highlighting significant inadequacies in the publicly available data; the limited number of research studies which explicitly link groundwater access to impacts on poverty (including some of the UPGro projects); and the limited understanding of how policies and practices in both water governance and social development sectors could lead to better and more sustained transitions out of poverty.

Code of abstract: T2.2.13
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Hand pump functionality: are the rural poor getting a raw deal?

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KEY WORDS water supply; groundwater management; Africa; poverty

ABSTRACT
Progress towards achieving the goal of universal access to clean water has been impressive, with the Millennium development Goals for access to clean water being met in most countries. However, these coverage figures may hide a more complicated picture where hand pumps (relied on by the rural and peri-urban poor for improved water sources) are not fully functional for part of the year. We report the results of a research project in Ethiopia, Malawi and Uganda where we have used careful survey and sampling design to accurately estimate the percentage of water points fully functional. We explore the use of different definitions of functionality: from a simple binary measure of working at the time of the survey, to a more comprehensive assessment of yield and reliability. We find that by using a randomised sampling approach and a more nuanced definition of functionality, rates in each country drop to below 50%. By adding in water quality indicators, rates fall even further. We argue that to improve reliable access to safe water for the rural poor a more systematic and robust measure of functionality most be used to track progress than coverage figures. This can bring into focus problems of poor functionality to enable the underlying reasons to be addressed.

Code of abstract: T2.2.14
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

GROUNDWATER AND POVERTY - EVIDENCE FROM KWALE, KENYA

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Keywords: Groundwater, Poverty, Socio-ecological Systems, Smart Handpumps, Kenya

ABSTRACT

Understanding groundwater and poverty linkages is critical to unlocking the potential of groundwater for poverty reduction. Central to accelerating and sustaining Africa's development is improving the understanding of how access to improved groundwater resources can benefit the poor. This includes (1) identifying the role of groundwater on productive uses such as livestock watering and crop irrigation (2) examining the relationship between poverty and changes in groundwater levels, and (3) understanding how groundwater dependency influences access to sufficient, affordable, reliable, safe, good quality water and physical access. One approach to explore these relationships is to consider groundwater as part of a socio-ecological system linking resource availability and quality with social systems managing and using the resource for domestic and productive uses. This framework provides a coherent, comprehensive and flexible diagnostic tool to characterise and explore interactions and outcomes between resource systems, resource units, governance systems and actors towards poverty reduction and equity, the sustainability of services and environmental sustainability.

Using Ostrom's socio-ecological system framework, we explore the associations between groundwater and welfare in Kwale County, Kenya, where poverty is widespread with around seven out of ten households estimated to live below the poverty line. Communities partly depend on water from 300 functional handpumps across the study area. We draw from a longitudinal household socio-economic survey data of 3,500 households and volumetric water usage data estimated from novel water data transmitters in 300 'smart' handpumps. We construct a multidimensional welfare index using indicators drawn from household composition, dwelling characteristics, asset ownership, sanitation and health, and drinking water variables. We further build a welfare map to understand spatial heterogeneity of welfare. Using this welfare data we test for the above associations drawing on data from the household socio-economic survey on productive uses, groundwater table depth, and drinking water services (sufficient, affordable, reliable, safe, taste, distance). Monthly data on volumetric usage of groundwater from each handpump is obtained from the water data transmitters while electrical conductivity data is obtained from the water quality campaigns.

Results show that the bottom welfare group is characterised by greater dependency on shallow groundwater, less acceptable drinking water services by taste, reliability, affordability or accessibility but not quantity. Productive use of groundwater for livestock accrues to the middle welfare quintiles with the bottom and top quintiles by choice or exclusion having little engagement. Overall productive uses of groundwater is modest for livestock (18% of households) or for small-scale irrigation (6% of households). The unusual availability of measured daily waterpoint usage provides novel data on usage illustrating similar groundwater usage patterns, on average, across all households. However, these patterns have seasonal dimension with rainfall predicting usage patterns. The causal relationships between resource system (shallow vs deeper groundwater, here) and welfare interact require further examination. Governance arrangements around community waterpoints vary considerably and are discussed to understand what interventions will improve welfare across socio-ecological systems interacting between governance and resource systems.

Code of abstract: T2.2.15
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.2. The role of groundwater in reducing poverty

Investigating the resilience of shallow groundwater resources in sub-Saharan Africa: a case study from Ethiopia

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KEY WORDS Shallow groundwater, groundwater modelling, climate resilience, citizen science, Ethiopia

ABSTRACT

Productive use of groundwater resources in sub-Saharan Africa currently remains low but is expected to increase significantly in the near future, potentially providing widespread poverty reduction. The accessibility of shallow groundwater resources means they are most likely to be used by poorer communities, but they are also the most vulnerable to overexploitation and climatic variability. Recent studies based on climate modelling and remote sensing data have demonstrated the abundance of groundwater resources at a broad scale, however, there is a scarcity of data to support its local management to reduce vulnerability.

Field investigations in Dangila, northwest Ethiopia, between 2014 and 2017 during the dry and wet seasons involved the setup of a community-based hydrometeorological monitoring programme, geological and water point surveys, community workshops, and sampling for major-ion, stable-isotope and radon-222 hydrochemistry. The fieldwork enabled development of physically based spatially distributed models using Shetran that were used to evaluate resilience of shallow groundwater resources for a range of climate and land use scenarios.

The simulations indicate an aquifer with varying potential productivity and vulnerability primarily dependent upon topography. Groundwater potential maps were produced that were validated by ground truthing and comparison with remote sensing vegetation indices. We show that groundwater storage and rates of groundwater recession are key factors in determining the potential to have a second growing season in many areas following the main rain-fed growing season. These results are useful for landuse planning by government ministries at national and *woreda* level, and by local communities to identify where interventions could have the greatest positive impacts.

Code of abstract: T2.3.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Dealing with consequences of haphazard urban development across a coastal lowland: Hydrogeological importance of the Cape Flats Aquifer system, South Africa

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KEY WORDS Urbanization, groundwater, disaster-risk reduction, aquifer management strategy

ABSTRACT
The unplanned, haphazard expansion of large cities presents a major problem globally. Cape Town, South Africa has experienced a phenomenal rate of urbanization with informal settlement sprawling across a low-lying marginal coastal area underlain by an important groundwater system, the Cape Flats Aquifer (CFA). Up to 1.7 million inhabitants experience: 1) variably limited access to water, sanitation and waste-disposal services; 2) high levels of unemployment and food insecurity; 3) vulnerabilities to environmental, flood-, human health-related and other hazards. Cape Town currently relies on water supplied via pipelines from large reservoirs in the eastern hinterland mountains. Increased storm-water runoff from urban and industrial areas, raw sewage flows from informal settlements, irrigation return flows from horticultural development, and releases from waste-water treatment plants have overwhelmed the through-flow and "kidney-function" capacity of the CFA system to cope with aqueous pollutants and nutrients, leading to eutrophication of coastal estuaries and surf zones and a perennial state of "groundwater flood", greatly exacerbated by increasingly variable winter rainfall. Problems of water (over- and under-) supply, pollution and overall environmental and social degradation have hallmarks of a classic slow-onset disaster, contributing to increasingly frequent and expensive public-health and disaster-management crises. Water-supply and –disposal problems therefore constitute the biggest risk to progress for the wider Cape Town metropolis, a microcosm of coastal urban society. Regeneration of CFA recharge zones and ecosystem services is an essential element of disaster-risk reduction to avert a potentially catastrophic outcome of present negative trends. Re-establishment of the natural water cycle through innovative water treatment, recycling and supply methods, the architectural landscaping of healthy public "green" spaces, and the generation of business and work opportunities underpinned by ecosystem services, can build community resilience, social and water security for the whole City of Cape Town. However, such goals require comprehensive exploration, monitoring, modelling and hydrogeological assessment of the CFA as part of a coherent aquifer management strategy.

Code of abstract: T2.3.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Groundwater security and sustainable development: the dilemma in atoll countries

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KEY WORDS - Atoll Sustainable Development, Groundwater Security

ABSTRACT
The 2014 UN Conference on Small Island Developing States in Samoa reaffirmed the vulnerability of small island states to natural and human-driven global changes and extreme events. Rapid population growth, projected sea level rise, increasing ocean acidification and changes in climate variability and frequency of extreme events, especially droughts, pose major challenges especially to communities in low-lying atolls and their groundwater systems. For these, and particularly those in population centres, environmental, social and economic sustainability is a critical priority. It is, however, constrained by increasing populations, increase in groundwater demand, restricted availability of safe and adequate water supplies, management challenges, very small land areas, limited waste disposal options and constrained resources. The dilemma faced is that continued development impacts directly on the very resources that sustains growth, especially fresh groundwater and near shore reefs. In this paper, we illustrate the dilemma faced by atoll counties in pursuing sustainable development and growth while ensuring water security in regions with highly variable climates, long and frequent droughts, scarce land resources and poorly developed governance and groundwater management regimes. Examples of atolls from both the Pacific and Indian Oceans are presented. Some options for addressing dilemmas are discussed, including the need for committed political leadership and atoll specific groundwater research.

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Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

How do new development activities affect coastal groundwater systems in Africa? The case of Kwale, Kenya

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KEY WORDS: Coastal Africa, groundwater, development, water resources management

ABSTRACT
Industrialisation and free markets are powering African growth in the 21st century. The African continent has huge potential for wealth generation from its extensive mineral resources; the scale of resource exploitation has grown rapidly in recent years following discoveries of hitherto unknown and economically viable mineral deposits. However, these new development activities, including not only mineral extraction but also industrial agriculture, are associated with an increase in water use and potentially reduced water quality, thereby affecting the availability of safe water resources for local communities.

Even though our understanding of Africa's sustainable growth and development has improved during the last decade, Africa's critically important groundwater systems are still poorly understood in the socio-ecological context. Some of the most vulnerable groundwater systems are located in the coastal zones of Africa. Groundwater systems in these densely populated areas are at high risk of saline intrusion, a risk which is exacerbated by a lack of knowledge of aquifer behavior.

In this study, we evaluate the potential impacts of diverse economic activities on the coastal aquifer system in Kwale County (Kenya) by means of kilometric geophysical profiles, hydrochemical and isotopic data across both dry and wet seasons, and groundwater level hydrographs. This area encapsulates the evolving situation in many parts of Africa: two multi-national companies have become established in Kwale County since 2012, augmenting the existing tourist industry. Base Titanium Ltd. is conducting the country's largest mining operation and KISCOL is developing 5,500 hectares of irrigated sugarcane. These companies and the communities living nearby exploit groundwater from a multi-layered aquifer composed of sand and limestone close to the surface and a fractured semi-confined sandstone and limestone aquifer at depth. Results indicate that geological structure plays an important role in determining the effect of these new development activities on water resources. They also suggest that, in this system, climate variation may have a greater influence on water resource quality and availability than new large-scale extractive use.

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Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
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Sustainable management of surface and groundwater resources of the Tensift basin (Morocco)

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KEY WORDS - SAD, GR2M, High Atlas, Water resources, Climate change

ABSTRACT
The Tensift watershed consists of a mountainous part serving as a water tower (the High Atlas) and an irrigated plain downstream (the Haouz of Marrakech). Irrigation water comes from the atlasic wadis, sometimes via transient storage by dams, as well as from the groundwater. This groundwater is mainly recharged, in the wadis, by infiltrations from precipitation in the mountains. The region's water resources are already subject to very strong tensions, which are expected to increase in the future as a result of anthropogenic pressure and climate change.
For a better management of the water resources of the Tensift watershed, a Decision Support System (DSS) was developed. This tool is based on four components: SAMIR (Satellite Monitoring of Irrigation), WEAP (Water Evaluation And Planning) and a Groundwater Flow Model (ModFlow).The implementation of the SAMIR-WEAP-ModFlow system contribute to finely evaluate the hydrological functioning of the Tensift catchment at the monthly time step and to develop management scenarios (new dam, basin transfer) or public policies (Reconversion to drip irrigation), or climate change and assess their possible impacts. In this context, the main objective of this study is to reconstruct the time series of the wadis flows of three sub-basins of the High Atlas (Rheraya, Ourika and N'Fis), which contribute to the recharge of the groundwater, using The GR2M conceptual hydrological model. A snow module has been incorporated into GR2M, to take into account the snow influence on the Tensift area. The GR2M has been calibrated and validated successfully over various periods in order to evaluate the robustness of its parameters for contrasting hydro-climatic conditions.
GR2M was also used to produce scenarios on the likely evolution of future water resources in these three watersheds. It was forced by the outputs of four Med-CORDEX Regional Climate Models (RCMs) under both scenarios RCP4.5 and RCP8.5. Forcing the hydrological model on the basis of the climate scenarios under consideration reveals that flows should continue to decrease by the end of the 21st century in the three atlasic basins. The performance of the GR2M model is generally satisfactory, according to the Nash criterion. Generally the results obtained are stable for the calibration and the validation whatever the chosen period, with a Nash criterion varying between 0.70 and 0.76 in calibration and between 0.43 and 0.68 in validation.
The assessment of precipitation simulated by the RCMs shows a strong underestimation, but a good reproduction of the cycle for the temperatures. For the three watershed, the projections for the 4 RCMs under both scenarios RCP4.5 and RCP8.5 show a rise in temperatures (+ 1.8 °, + 2.2 °) for N'fis, (+ 1.7 °, + 2.3 °) for Ourika and (+ 1.55 °, +2.17) for Rheraya, in conjunction with a decrease in total precipitation (-16% , -26%), (-15%, -26%) and (-16%, -28%) respectively. Forecasts of flows (2040-2056) show a large expected decrease in surface runoff (-48%, -63%), (-53%, -69%) and (-38%, -59%) respectively, due to reduced precipitation and increased temperature.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Source Water Protection Strategies for Karst Aquifers

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ABSTRACT
Karst terrains and their underlying aquifers are noted as being highly vulnerable to contamination from a wide range of anthropogenic sources and activities. Worldwide, karst aquifers are important water supplies for municipalities, agricultural, and industrial users. In addition, they provide habitat for many unique and endangered species. This paper will discuss the strategies to protect karst aquifers through an integrated planning approach at the local, regional and federal level. Components of a comprehensive strategy including data collection related to groundwater quality and quantity, delineation of groundwater flowpaths, basin boundaries, and groundwater velocities; identification of potential contamination sources; recommendations on monitoring parameters and frequency; coordination for the response to hazardous materials releases; and zoning and land use restrictions.

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Topic: T2. Sustainable Management of Groundwater Resources
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Visual KARSYS – a web-tool for the documentation of karst aquifers

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KEY WORDS Karst, 3D models, groundwater management, web-service

ABSTRACT
Groundwater management in karst regions is still a challenge in various parts of the world due to the lack of understanding and of dedicated tools. Existing knowledge about geology and hydrology are usually not synthetized in an optimal way, making difficult to produce a clear conceptual model of the karst flow systems, showing the geometry of the aquifer, the catchment boundaries and the main flowpaths. Such conceptual models are however essential for application (groundwater well boring, assessing karst related hazards in underground construction, etc.), and/or for designing further investigations on site (geophysics, dye tracing tests, etc.). SISKA developed a pragmatic and 3D-based approach – KARSYS (Jeannin *et al.* 2013) – for the documentation of karst aquifer. This approach provides a conceptual model of aquifers and flows. KARSYS helps decision makers, engineers and hydrogeologists to get a pragmatic and consensual information in order to take the best decisions regarding groundwater management. As the application of KARSYS deals with several software packages and requires a long training, SISKA is now working on Visual KARSYS, which is a web-tool for the users to apply KARSYS by themselves through an intuitive web-based interface.
Visual KARSYS adresses two types of users: modelers and end-users. Visual KARSYS will guide modelers through the KARSYS's steps and will provide them essential tools to establish their own karst aquifer models by using their own data set. Visual KARSYS will also include a dedicated module to end-users (e.g. water authorities), who could view and interrogate the data/results produced by Visual KARSYS via a 3D-Web viewer.
The talk intends to present the concepts and the architecture of the Visual KARSYS web-tool and the related fields of application.

The Visual KARSYS project is supported by the grant for Innovation and Technologic development from the Swiss Federal Office for Environment.

References

Jeannin PY, Eichenberger U, Sinreich M, Vouillamoz J, Malard A et al. (2013) KARSYS: a pragmatic approach to karst hydrogeological system conceptualisation. Assessment of groundwater reserves and resources in Switzerland. Environmental Earth Sciences, 69(3): 999-1013 p.

Code of abstract: T2.3.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Towards Sustainable Groundwater Management in the Valle Alto de Cochabamba, Bolivia.

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KEY WORDS groundwater, sustainable management, irrigation, groundwater recharge

ABSTRACT
The Valle Alto de Cochabamba is an important agricultural region in Bolivia. The annual precipitation is approximately 500 mm and mainly falls in the rainy season between November and March. Consequently, agriculture depends on irrigation with much of the water sourced from groundwater. Studies by the Universidad de San Francisco Xavier and Universidad de San Simon along with anecdotal evidence indicate some areas in the valley have had significant levels of groundwater decline, indicating a need for sustainable groundwater management. We report on our experiences in the Cliza Municipal District during the years 2013-2015. Groundwater recharge is complicated with chemistry data indicating multiple sources which most likely include flood irrigation. Additionally, major floods that occur every several years may play a critical recharge role. Long term monitoring of water levels and irrigation scheduling is required to understand the timing and quantity of recharge which is required for sustainable groundwater management. However, operational challenges exist and social context must be considered when designing studies and developing management strategies. There were over 140 water wells operating at the time of our study, with dozens of independent water well management groups. The local populace is independent, distrustful of government authorities and will not tolerate imposed solutions (this is the region where the 1952 revolt that lead to agricultural land reforms began). The municipal government, while expressing good intent, is an unreliable partner because a change in the elected government results in a complete change in the technical staff. Consequently, it is critical to establish long-term relationships with the water well user groups. They have demonstrated a strong interest in water resources. One must work directly with these stake holders to design and implement water well monitoring networks as well as the monitoring of flood irrigation. Additionally, frequent meetings with these groups are required to update them on the results of studies, to develop a shared understanding of the significance of the results and to develop stake holder visions for management strategies. This is a long-term process that will require time and a consistent commitment of resources.

Code of abstract: T2.3.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Collective action in groundwater management – Lessons learnt from the Angas-Bremer irrigation district, South Australia.

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KEY WORDS: Integrated groundwater management, collective action, co-management, socio-hydrogeology, community engagement.

ABSTRACT

Since the early 1980's the Angas Bremer (AB) catchment in South Australia provided a rare example of collective action amongst irrigators to manage groundwater resources. By closely working internally and with government agencies, the AB community successfully recovered an aquifer that was at risk of depletion and salinization.
It has been increasingly recognized that resource-user engagement in decision-making, through local collective action, is likely to offer effectiveness to groundwater management, which in turn can prevent groundwater depletion. However, the formal frameworks developed to facilitate resource-user participation in management have mainly been focusing on institutional designs in isolation, often neglecting to incorporate important factors such as social, historical and ecological contexts in which those institutions were created. Those specific contextual factors play a critical role in determining whether resource users are likely to work together towards the common goal of sustainably managing groundwater resources.
The key questions of this research analyze (i) the extent to which AB was an example of collective action, (ii) how that has changed over time, (iii) why it occurred, and (iv) the key outcomes of collective action. These research questions aim to identify the main factors that facilitated or impeded collective action in groundwater management in an Australian context.
Through a series of semi-structured interviews to further explore the context under which collective action arose, as well as to understand individuals' perspectives and experiences, this study provides a summary of qualitative research that set out to describe how the AB groundwater system has been managed over time and identifies lessons from that experience.
The findings show that human and social capitals, including the norms and values of resource users, have a strong role in determining the successfulness of management approaches. Moreover, a trustworthy two-way relationship between resource users and formal institution is required. By exchanging knowledge and understanding each other's norms and values, the resource users' acceptance of management policies is greatly enhanced.

Code of abstract: T2.3.9
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Geological Society of America Hydrogeology Division 2017 Birdsall-Dreiss/LaMoreaux Lecture - Water Resource Stewardship in the U.S. National Park Service

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KEY WORDS – U.S. National Parks, water resources, conservation, management

ABSTRACT
The Geological Society of America (GSA) Hydrogeology Division announces a new international component to its Birdsall-Dreiss Lecture series. Henceforth, international lectures will be given in honor of Drs. Philip and Bunnie LaMoreaux. Philip was a founding member of the Division and a past President of the International Association of Hydrogeologists. Bunnie developed the University of Alabama International Student Program. The U.S. National Park Service (NPS), preserves unimpaired the natural and cultural resources and values of the U.S. National Park System for the enjoyment, education, and inspiration of this and future generations. This mandate also applies to park water resources. Parks face many water resources challenges - some inherited, some created unintentionally by other management actions, and some driven by dynamic change in the environment all requiring unique and creative management solutions. Also, unlike most park resources, that are located largely within park boundaries, or are under the management control of the NPS, park water resource issues and management often involve greater challenges that arise because watershed and aquifer boundaries extend beyond park boundaries and because the legal authority to allocate and manage water resources typically resides with the states. Thus, parks have to consider resource issues at a larger landscape scale, and manage collaboratively with neighbors and partners. Additionally, water resource funding and expertise may be limited within parks, resulting in the need to partner with other agencies, states, universities, friends groups, or regional and national NPS offices. Lastly, park water resource issues may have broader legal, political, socioeconomic, and cultural implications requiring park managers to consider more than just the science alone when making a management decision. The lecture explores the process of how parks identify water resource needs and issues, obtain the necessary science, and develop and apply that science to make water resource management decisions given challenges such as organizational structure, regulations, trans-boundary issues, partnership building, funding, expertise, and making science-based decisions that also appropriately consider legal, political, socioeconomic, and cultural impacts.

Code of abstract: T2.3.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

World-wide Hydrogeological Mapping: The World Karst Aquifer Map

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KEY WORDS: World-wide hydrogeological mapping, water resources management, carbonate rock, karst aquifer

ABSTRACT
Karst aquifers deliver freshwater to hundreds of millions of people. In many regions, karst groundwater is the major source of drinking water supply and used for irrigation agriculture. Large cities such as Vienna, Rome, San Antonio and Taiyuan, rely predominantly on karst water. Climate change and population growth will increase the pressure on these resources. The exploitation and protection of karst aquifers is challenging, because of their specific hydraulic properties. Karst systems are often very large, thus requiring transboundary management. The World Karst Aquifer Map (WOKAM) is a new map of the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP) series and intends to facilitate global water-resources management.
The WOKAM mapping units "carbonate rocks" and "evaporites" represent potential karst aquifers. Their actual degree of karstification and their hydraulic properties cannot be determined at global scale, but it is safe to assume that most exposed carbonate and evaporitic rocks are karstified to some degree. The "carbonate rocks" mapping unit includes the whole range of sedimentary and metamorphic carbonate rocks: Limestone and dolomite are the most widespread sedimentary carbonate rocks, but marble and other metamorphic carbonate rocks also form relevant karst aquifers in some regions. Carbonate and evaporite areas were subdivided into continuous and discontinuous zones, based on an area's share of the respective rock type. Areas with more than 65% of carbonate or evaporite rock were generally mapped as "continuous"; areas between 15 and 65% were mapped as "discontinuous." Zones where exposed carbonate rocks plunge beneath adjacent non-karst formations are indicated by a line of triangles pointing to the direction of non-exposed carbonate rocks, which may constitute deep freshwater or thermal water aquifers. The map also presents a selection of important caves and karst water sources, including submarine and thermal springs.
WOKAM allows a more precise global quantification of karst systems. The map will help to increase awareness of karst groundwater resources in the context of global water issues and serve as a basis for other karst-related research questions at global scales, for example related to climate change, biodiversity, food production and urbanization.

Code of abstract: T2.3.11
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Risk assessment of losses of the groundwater resources in Azerbaijan Republic caused by climatic changes

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KEY WORDS - water resources, groundwater, climate change, risks of extra losses.

ABSTRACT

The major part of the territory of Azerbaijan Republic locates in arid climatic zone with the limited water resources. The existing deficit of water economy balance of the Republic exceeds 30% of the actual resources. At the same time 70% of the total resources consist of trnasboundary river water and groundwater. In the nearest future the passage of 40% is as sure as fate, but this is the threshold of the water crisis when the water lack will limit the agriculture development and, as a result, the food security, industry development and the economy as a whole. At the same time the scenarios of forecasts of the climate change point to risks of extra losses of the water resources. The present paper deals with modern state of the general water resources within the country and the groundwater in particular as well as the risk analysis had been carried out; the ways of assessment of various degrees of vulnerability of the general water resources had been shown as well as the risks of losses caused by the climatic changes.

Thus, the water resources represent an important object when studying the potential impact of the climate. The results of above-mentioned investigations show that the climatic impact needs extra studied, with further focus on risk assessment because the quantitative assessment of risks for the observed systems can be useful in cases when one have to manage these risks and to select the appropriate ways of losses reduction of water resources.

Results of studies of water resources changes show that over the last years the slow reduction of river flow is observed; the noticeable redistribution of flow during the year had happened. The calculations results show that the reduction of water resources for 5,7-7,7 km^3 is expected if all three scenarios realize. As the present water deficit about 5 km^3 its value can increase to 9,5-11,5 km^3 till XXI present, at the same time the most vulnerable branches of the economy will be the power economy, agriculture and population supply with potable water.

Taking into account the existing desperate deficit of water balance the earlier-developed technique of risk assessment is adopted here to the existing conditions within the country. In the present case under the risk one understand the value characterizing the possibility and hazard of situations origin leading to loss of some water resources within the situation of the existing deficit (F.R.Farmer,1967). According to the present principle the dependence of frequency (probability) of the uncontrolled situations (in the present case the water resources loss) upon their consequences is built. In the present case the consequences are the water resources losses.

Code of abstract: T2.3.12
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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Estimation of optimal pumping rate at a production well

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KEY WORDS production well, pumping time, time-drawdown, optimal pumping rate

ABSTRACT
The geology of the area is composed of consolidated sedimentary rock and metamorphic rock. Therefore, groundwater yield of the wells in the area is low compared with those of other region. At present, just one borehole is used for community groundwater system (CGS) to serve groundwater as domestic water of the area but radon concentration of the water is about 550 Bq/L. To develop another CGS of the area, a 100 m depth well was drilled. The optimal pumping rate of the well was estimated by two times of constant rate pumping tests. The first pumping test lasted for 1,470 min at pumping rate of 71 m^3/d. Transmissivity (14.37 m^2/d) and storage coefficient (3.83×10^{-4}) was calculated from the pumping rate and the time-drawdown data obtained from the observation well. The pumping rate of the second pumping test was 117 m^3/d. An impervious boundary effect occurred 120 min (drawdown 28 m) after the pump was started. During the pumping tests water quality and the radon contents of the water were measured. The water temperature varied from 12.7℃ to 12.1℃ and oxidation-reduction potential (ORP) varied from 186 mv to 326 mv indicating as pumping time going on the percentage of shallow groundwater is increasing. Time-drawdown and water quality variation data obtained from pumping tests reveal that optimal pumping rate of the developed production well is about 90 m^3/d.

Code of abstract: T2.3.13
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Country Index to Assess Potential Agricultural Development through Sustainable Surface and Groundwater Management

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KEY WORDS Sub-Saharan Africa, sustainability, rain fed, irrigation

ABSTRACT

Agriculture is the primary source of livelihood in the Sub-Saharan Africa. This sector contribute in 32 percent of total gross domestic product of Sub-Saharan countries, and employs 65 percent of the labor force. Still only a portion of the Sub-Saharan cultivable land area is farmed, as low as 10 percent in many countries. Agricultural activities are based on small scaled farming, and rain fed agriculture comprises more than 95 percent of the total cultivated land area. Sub-Saharan countries are currently using 5 percent of its available renewable water resources. The aim of the study is to check the renewable water availability, both surface and groundwater, needed to increase the farmed area in 15 selected Sub-Saharan countries. An index was developed in order to classify the selected countries, based on the availability of renewable water resources versus the new water demand. Classification is divided into six classes, from either surface of groundwater are higher than the new water demand, to countries where current agricultural water consumption is higher than the renewable resources. For calculating the water demand, three scenarios were assumed depending on farming methods used in these countries, rain fed, irrigated or a mix of both. The data used is from the "Aquastat" information system, developed by the FAO land and water division. Results show that except for Zimbabwe, the current available surface or groundwater resources are sufficient to fully cultivate the whole potential areas in the selected countries, where a cultivated area is developed using both rain fall and irrigation. For cultivation using only irrigated systems, each of Niger, Burkina Faso, Mali, Kenya, Tanzania and Zimbabwe lack the needed renewable water resources.

Code of abstract: T2.3.14
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.3. Sustainable management of groundwater resources worldwide – what have we learned?

Hydrogeological and Hydraulic Characterization of Weathered Crystalline Basement Aquifers of Ibarapa Area, Southwestern Nigeria

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KEY WORDS - Crystalline basement rocks, Weathered aquifer, Pumping tests, Hydrogeological characterization, Hydraulic properties

ABSTRACT

Reliable estimates of aquifer parameters are fundamental to understanding of sustainable groundwater development and management, especially in the crystalline basement settings with complex and erratic groundwater bearing zones. Therefore, this study focus on the use of resistivity survey (82 vertical electrical soundings) and pumping (hydraulic) tests of 21 boreholes to characterize the hydrogeological and hydraulic properties of the dual weathered–fractured aquifer system of the crystalline rocks of Ibarapa areas of SW-Nigeria.

The geo-electric survey revealed predominantly 3-layers H-type curves with estimated total regolith thickness of 4.4 - 47.5m (av. 18.0m) for both amphibolites and banded gneisses bedrock settings compare to the shallower thickness of 2.4-23.6m (12.2m) for areas underlain by migmatite and granite, implying varied degree of weathering. Hydraulic characterization revealed that the weathered-fractured aquifer in areas underlain by amphibolites have higher transmissivity of 1.11 – 7.75m^2/day (av. 4.11m^2/day) and hydraulic conductivity values of 0.39-4.51 x 10^{-6}m/s (1.56 x 10^{-6}m/s) compared to areas underlain by migmatites with lower transmissivity of 0.56-0.73 m^2/day, (av. 0.69 m^2/day) and hydraulic conductivity of 0.28-0.38 x 10^{-6}m/s (av. 0.34 x 10^{-6}m/s). However, areas with gneisses and porphyritic granite have moderate transmissivity with average of 1.61 m^2/day and 1.43 m^2/day and average hydraulic conductivity of 0.66 x 10^{-6}m/s and 0.85 x 10^{-6}m/s respectively. These are consistent with the relatively higher estimated discharge of 43.56 - 98.12 m^3/day (av.72.05 m^3/day) for amphibolites compared to migmatites with 41.91 - 99.79 m^3/day (67.97 m^3/day), granite with 45.62-91.01 m^3/day (62.79 m^3/day) and gneisses with the lowest yield of 32.78 - 78.92 m^3/day (av.53.45 m^3/day).

Based on the overall results, areas underlain by amphibolites and gneisses are characterised to have lower recharge attributes due to development of more clayey regolith soils while the regolith unit associated with porphyritic granite have good recharge potential due to the development of more sandy soils. This clearly highlights varied hydraulic and the need for sustainable management of groundwater system in a typical basement terrain.

Code of abstract: T2.4.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Economics of recharge augmentation by four check dams on ephemeral streams in a hard rock area of Rajasthan, India

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KEY WORDS - cost-benefit analysis, managed aquifer recharge, maintenance of recharge structures, irrigation supplies

ABSTRACT
This paper reports results of a simple low cost water balance study over three years 2014-2016 to determine recharge from four check dams in ephemeral streams in a hard rock area in the Dharta watershed, Udaipur district, Rajasthan, India. This is linked to economic costs of construction and maintenance of the check dams to enable a unit cost to be derived and compared with the economic benefits arising from the additional irrigation enabled by check dam recharge. Results for 2014 a typical year (480-770mm rainfall in 20-30 rain days), showed that recharge from the four check dams amounted to 1 Mm^3, accounting for an estimated 70% of inflow. The estimated recharge was sufficient to supply irrigation for 65 ha of dry season crops, amounting to 18% of the irrigated area. Over the 3 years of the study several check dams were scraped in the dry season by either mechanical equipment or by hand labour to remove low permeability silt that restricted infiltration. It apperas that dry weather infiltration rates increase more when check dams are scraped by hand labour than when mechanical scraping is performed. The economic analysis, which will be completed in June 2016, is expected to suggest criteria defining whether scraping should take place in the following dry season. The mean annual cost of required maintenance as a percentage of capital costs of investment in check dam construction will be derived. This information is a starting point to inform future investment in currently considerable government and NGO programs for check dam construction and maintenance in semi-arid hard rock areas of north west India.
This work was performed as part of the Managed Aquifer Recharge through Village-level Intervention (MARVI) project (Maheshwari *et al* 2014), which is funded by the Australian Centre for International Agricultural Research. Techniques for daily monitoring are basic, and in 2015 and 2016 were performed by farmers, with quality control processes in place. A mobile phone app is being developed with a view to enabling farmers to evaluate dry weather infiltration rate and assist local water management institutions to prioritise requirements for scraping of their local checkdams, without the need to depend on inputs from government agencies.
Reference: Maheshwari, B., M. Varua, J. Ward, R. Packham, P. Chinnasamy, Y. Dashora, S. Dave, P. Soni , P. Dillon, R. Purohit, Hakimuddin, T. Shah, S. Oza , P. Singh, S. Prathapar , A. Patel , Y. Jadeja, B. Thaker, R. Kookana, H. Grewal, K. Yadav, H. Mittal , M. Chew , P. Rao (2014). The role of transdisciplinary approach and community participation in village scale groundwater management: Insights from Gujarat and Rajasthan, India. Int Open Access J Water, 6(6) 3386-3408. http://www.mdpi.com/journal/water/special_issues/MAR

Code of abstract: T2.4.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

ARTIFICIAL GROUNDWATER RECHARGE USING DEEP WELLS: EXPERIENCES AT MADRID TERTIARY DETRITAL AQUIFER.

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KEY WORDS Groundwater recharge, water management, artificial recharge, aquifer, Canal Gestión, Madrid

ABSTRACT
Canal de Isabel II Gestion (Canal Gestion) is the main provider of water and wastewater management services in the Madrid region, supplying over six million consumers. Supply is accomplished through 14 dams which storage 946 hm3. During extended periods of drought and/or disruptions in the water supply system, Canal Gestion is able to produce up to 90 hm3 per year from 79 wells located in the Madrid Tertiary Detrital Aquifer (ATDM). Over the last 23 years, Canal Gestion has produced 289 hm3 from the ATDM in five main pumping periods, each ranging from 12 to 18 months. Between extraction periods, groundwater level recovers to its initial position. In 2004, an average of 20 m of residual drawdown was observed in the well network. In 2008, Tajo River Basin Authority published "Schema of Important Issues", outlining aquifer recharge as a measure to reach good quantity status of groundwater bodies.
In order to study the feasibility of groundwater recharge, Canal Gestion installed three groundwater recharge stations. Each station is composed of an Aquifer Storage and Recovery (ASR) well and two nests of three piezometers. The observation well network was completed with existing wells in the surrounding area. A total of three recharge tests were conducted from October 2010 to July 2012.
Each test consisted of a three-month recharge phase followed by one month of recovery before starting the subsequent recharge cycle. Once the recharge test was completed, the aquifer was not disturbed for one year before recovery pumping was initiated.
Feasibility of groundwater recharge using deep wells in the ATDM was proved. The volume of water recharged was a substantial percentage of the water right conceded by Tajo Water Basin Authority at each well. During the pumping period at the end of the recharge test, the recharged water could be fully recovered. Moreover, drinking water quality was achieved after a basic disinfecting process. Artificial groundwater recharge has demonstrated its efficiency as a management tool to reduce the net volume extracted from the aquifer. Data collected from recharge tests will be used to improve well design and equipment involved in the process.
Future works, in the same manner as the EU Water Framework Directive, will require a lawful analysis of the water right concession in order to expand water recharge techniques to other wells in this aquifer. It has been proved that groundwater recharge can help to accomplish a good quantitative and qualitative status of groundwater bodies.

REFERENCES
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (2000) L327/1
Schema of Important Issues, Tajo River Basin Authority (2008). Madrid, Spain
Tajo River Basin Management Plan (RBMP) 2009-2015 (2009). Madrid, Spain.

Code of abstract: T2.4.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Estimation of the screen length effect on injection wells

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KEY WORDS laboratory aquifer-well system, screen length, injection wells, managed aquifer recharge

ABSTRACT
Aquifer storage and recovery (ASR) is one of the most used techniques for the managed recharge of aquifers around the world. The method implies using infiltration wells to store the water in the subsurface when it's easily available and using the same wells to recover it during periods of high demand. Due to different physical-chemical characteristics and aeration degree of the injected water, the ASR wells are more prone to clogging that the regular pumping wells. For this reason, the screen length is usually designed twice that of a pumping well. However, the injection of high quality water or physical limitations given by local geological strata might lead to utilisation of shorter screen lengths. In this case, it is important to know how the screen length influences the general system's efficiency, especially with regard to the maximum infiltration rate and dynamic level of the aquifer. To answer this question, the present study investigates the correlation between the screen length and the injection rates in a special designed laboratory aquifer-well system (LAWS) that simulates a phreatic aquifer. The LAWS consists of a cylindrical tank with the diameter of 1.0 m and height of 1.2 m. Tap water is injected at different pressures and infiltration rates in a fully penetrating well with the dimeter of 0.1 m installed in the centre of the tank. The well screen length is progressively changed by blocking the screen with an inflatable packer. The preliminary results of the experimental infiltration show that the screen length has almost no effect on the infiltration rate but a high effect in the dynamic level in the well. This should be taken into consideration in the design of ASR wells.

Code of abstract: T2.4.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Mapping aquifer productivity in the Sahel region: Harmonization of transboundary maps

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KEY WORDS aquifer productivity, map harmonization, general legend, lithology, Sahel zone

ABSTRACT

Population growth, climate dynamics, and global warming are strongly increasing stress on the water resources in the Sahel zone. To handle the challenge of limited water supply, groundwater is used extensively, often without proper management strategies.
To strengthen regional groundwater management in the Sahel zone, technical cooperation projects of the Federal Institute for Geosciences and Natural Resources (BGR) support the transnational commissions of Lake Chad Basin (LCBC) and Niger Basin (NBA), the regional authorities on water resources. With five, respective nine, member states the two authorities are responsible for the sedimentary basin each extending over more than 1,000,000 km^2, located mostly in the semi-arid Sahel zone.
As a basis for decision making, reliable spatial information on groundwater resources is essential. Therefore, a process chain has been implemented to harmonize available national data on lithology and geology and to elaborate transboundary maps of aquifer productivity for several pilot zones. Legend descriptions available from analog lithologic maps were harmonized based on the hierarchical scheme of the lithological legend of the International Hydrogeological Map of Europe (IHME 1500). Final aquifer productivity classes were established applying transfer rules on the obtained harmonized lithological legend, and by integrating information on bore logs and pumping tests. Verification by local experts of the respective basin authorities took place. GIS processing steps include spatial adjustment and geometric harmonization of national lithological source maps.
The elaborated unified lithology and aquifer productivity maps provide the basis for further assessment of hydrogeological themes such as vulnerability to climate change, pollution, groundwater recharge and the identification of potential zones for managed aquifer recharge.
The outlined process chain represents a reproducible method to harmonize heterogeneous lithological and hydrogeological information and is envisaged as a blueprint for the compilation of further harmonized maps on a regional level.

Code of abstract: T2.4.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Links between the presence of snowpacks and groundwater recharge – Simulation results for the territory of Slovenia

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KEY WORDS groundwater recharge, snowpack, mGROWA, Slovenia

ABSTRACT
The implementation process of the EU water legislation (EU WFD, EU GWD) has put pressure on hydrogeologists to create, analyse and disseminate groundwater recharge maps in high temporal and spatial resolution for sustainable water management. The distributed water balance model mGROWA is currently applied in several European countries in order to create such maps. Applying mGROWA to country-specific prevailing climatic and hydrogeological conditions requires adaptations of the methodology with regard to the model setup and implementation. In contrast to many lowland regions in Western and Southern Europe, groundwater recharge in many Slovenian aquifers is limited during winter months due to water retention in snowpacks. Against this background the mGROWA model has been enhanced in a Slovenian-German research cooperation by procedures for the simulation of relevant processes associated with formation and melting of snowpacks. In combination with the multi-layer soil water balance module which was already implemented in mGROWA, this new feature enables a realistic simulation of inner-annual variations of groundwater recharge patterns in European alpine and highland areas in daily time-steps on a 100 m grid.
In this contribution we briefly introduce the mGROWA methodology and the newly implemented snowpack module. Subsequently, model results for the reference period 1971-2014 are shown. This includes on one hand the evaluation of the simulated snowpack presence by using observations at about 400 sites and an assessment of the evolution of days with snowpack during winter. On the other hand, simulated groundwater recharge rates are evaluated with observed stream flow hydrographs and base-flow derived from these. In this context, also the impact of simulating temporal snowpack presence on groundwater recharge patterns is presented and discussed with a few examples. Finally, the consequences of addressing snowpacks in groundwater recharge assessments will be discussed with regard to the implications for management strategies for sustainable use of groundwater resources in Alpine regions.

Code of abstract: T2.4.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Mapping groundwater recharge with associated uncertainty at the regional scale

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KEY WORDS: groundwater recharge, mapping, uncertainty, infiltration processes, France

ABSTRACT
Assessing the groundwater recharge can represent a challenge due to the generally limited knowledge about infiltration processes, interaction with surface water or between aquifers, available data and pumping impact on it. Using different methods to estimate recharge is recommended in order to integrate uncertainties. Nonetheless, only some of the existing recharge estimation methods allow mapping groundwater recharge at the regional scale and providing a spatial resolution in accordance with water management decision scale.
A gridded water budget approach has been developed to compute at the daily time step, the groundwater recharge by precipitation at the regional scale of the south of France. Independent water budget approaches are compared between them and with the SURFEX land surface modelling results to assess the uncertainty associated to the effective rainfall parameterization method. A distributed parameter (IDPR) related to the drainage density and which accounts for hydrological connectivity have been calibrated to provide the gridded effective rainfall infiltration coefficient necessary for recharge estimation. Independent recharge evaluations at the catchment/aquifer scale are included in the analysis to assess the part of the total recharge taken by the infiltrated precipitation.

Code of abstract: T2.4.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Promoting the Capture Principle Approach to Sustainable Groundwater Use in South Africa

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KEY WORDS Groundwater recharge/water budget, capture principle, numerical modelling, sustainability

ABSTRACT
The scientifically accepted principles of groundwater flow theory dictate that on pumping, water levels will decline, natural discharge may decline, and recharge may increase. This decrease in discharge or increase in recharge has been termed "capture" of water (Lohman 1972, Seward et al. 2006). It follows that an assessment of the sustainability of groundwater abstraction would estimate these changes in the flow regime, and determine whether the changes and their associated impacts are considered socially, economically and environmentally acceptable; termed here the capture principle approach to sustainable groundwater use.

However, many groundwater management approaches in South Africa apply water balance type calculations in which groundwater availability is directly linked to a portion of pre-abstraction recharge. These calculations are often performed over surface water catchment areas, and areas with high use compared to recharge are identified as "stressed". The underlying assumptions, (over) simplifications and limitations of the approach are not always made explicit, potentially limiting groundwater development based on a perceived stress.

This paper assesses the degree to which the capture principle approach to sustainable groundwater use is mainstreamed into guidelines and tools for groundwater use in South Africa. The assessment reveals a lack of guidance on or specific discussion of the process by which the estimated conditions at future dynamic equilibrium are considered acceptable or not, and the required hydrogeological input to this consideration. Whilst numerical modelling is often used for assessment of impacts on water levels, changes in the flow regime are often not estimated. Based on the identified gaps, two aquifer systems are selected as case studies. One of which is a karstic aquifer in which abstraction is >95% pre-abstraction recharge, maintained by enhanced recharge. The second is an alluvial aquifer discharging to a highly sensitive lagoon. In each, numerical modelling is carried out to estimate changes in the flow regime under abstraction and the relationship between abstraction and reduced discharge is quantified. The paper reveals insights into the applicability (scales and situations), of the capture principle approach to sustainable groundwater use.

Code of abstract: T2.4.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

The costs of managed aquifer recharge

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KEY WORDS Managed aquifer recharge, schemes, costs

ABSTRACT
The use of groundwater is increasing in many countries in response to the rising demands for drinking water supplies and food production for a growing global population. Groundwater supplies are diminishing and 20% of the world's aquifers are overexploited. Managed aquifer recharge (MAR) encompasses a range of technologies and management methods that can improve groundwater recharge and maintain aquifer resources. There are many examples from around the world that demonstrate the wide range of benefits of MAR, but uptake of MAR has been lower than expected. The financial and economic performance of MAR is a key determinant of the global uptake of MAR but there are very few studies that demonstrate the financial viability and performance of different kinds of MAR schemes. The economics working group of IAH MAR has started a program of studies to address this deficit. This initial study contains an analysis of financial data from 22 MAR schemes from 5 countries. Although these MAR schemes are highly heterogeneous it is possible to draw some conclusions about major factors that affect scheme costs. The costs of MAR schemes vary substantially between MAR types. Schemes using natural infiltration and spreading basins using untreated water are relatively cheap, schemes using wells, bores and expensive infrastructure are relatively costly. When water treatment is needed this involves significant extra costs. Project objectives and scale, Infiltration rates, well yields, operating periods and storage losses also have a significant influence on costs in specific cases. Priorities for further research include additional disaggregation and analysis of capital and operating costs, inclusion of more cases from developing countries and analysis of the cost effectiveness of MAR compared with alternatives.

Code of abstract: T2.4.9
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Evaluation of Managed Aquifer Recharge Site Suitability for the North China Plain

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KEY WORDS - Managed aquifer recharge, GIS analysis, Suitability, North China Plain as one of the global hotspots for groundwater depletion.

ABSTRACT
Remote sensing and groundwater level observation data have consistently identified the North China Plain (NCP) as one of the global hotspots for groundwater depletion. Groundwater flow modeling studies have found that pre-development storage is estimated to be 1500 km^3 of drainable storage in shallow aquifers and 40 km^3 of compressive storage in deep aquifers, while simulated groundwater depletion from 1960s to 2008 averaged 4 km^3/yr. Such modeling studies also found that a combined strategy involving managed aquifer recharge, water conservation measures augmented by the South-to-North inter-basin transfer is necessary to "recover" groundwater storage by 50 km^3 over 15 years. The water demand in the NCP is unlikely to decline in the near future as the Chinese government has committed to further develop the Jing-Jin-Ji urban corridor consisted of 100 million people, including a recent announcement to establish the Xiongan New Area located approximately half way between Beijing City and Baoding City of Hebei Province. This study aims to assess the suitability of site for managed aquifer recharge in the northwestern NCP where Shijiazhuang-Baoding-Beijing are located, encompassing the Xiongan New Area. Hydrogeological and environmental geological surveys took place in 2015 and 2016 from the mountain piedmont areas located in the west down to the plain areas to the east where groundwater discharges to Baiyangdian Lake. A GIS analysis was conducted based on 11 types of data: (1) surficial geology, (2) soil infiltration capacity, (3) land use, (4) elevation (topographic slope), (5) vertical infiltration coefficient, (6) aquifer thickness, (7) aquifer hydraulic conductivity, (8) confining layer thickness, (9) aquifer storativity, (10) vadose zone thickness, and (11) historical changes in water table elevation. These factors were analyzed following the method described by Russo et al 2015 to arrive at a managed aquifer recharge suitability index score. The results show that a total of area 498km^2 is potentially suitable for manage aquifer recharge, primarily consisted of piedmont alluvial fan deposits and the downgradient river channels, specifically, Juma River alluvial fan , Jie River alluvial fan, Shahe River Channel located in Xinle City, Ci River channel from Gaocheng Xiguan town to Wuji town. Infiltration experiments in these areas are necessary to verify the vertical infiltration coefficient.

Code of abstract: T2.4.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Potential of using Managed Aquifer Recharge to restore groundwater aquifers in North China Plain

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KEY WORDS - Water balance, Managed Aquifer Recharge, South-to-North Water Diversion Project, North China Plain, MIKE SHE

ABSTRACT

Water crisis in North China Plain (NCP) has deepened over the past decades due to both climatic and anthropogenic pressure. NCP is located in the continental semi-arid region, where the potential ET is higher than precipitation. In addition, rapid population and economic growth in this region has also created steep rising water demand. Since natural surface water bodies have gone dry over the past years, the extra water demand relies almost entirely on groundwater abstraction. As a result, the groundwater table has declined at a terrifying speed which can be up to 1 m/year in NCP. In order to stop this trend, the South-to-North Water Diversion Project (SNWDP) was initiated and the middle route was fully operational in 2015. However, the diverted water is used mainly for domestic and industrial water supply in and round the cities, and the treated wastewater (reclaimed water) is largely discharged through existing river channels, generating a source of unmanaged groundwater recharge; meanwhile, groundwater abstraction takes place primarily in agriculture. Although it might not be the perfect solution, Managed Aquifer Recharge (MAR), either purposeful or in lieu recharge, appears to be the only solution there left to restore the depleted aquifer system in NCP. MAR is used worldwide in different applications to replenish overexploited aquifers and to improve water quality, since the water is purified when passing through the soil and aquifer sediment, and ultimately increases the groundwater recharge. The present study aims to explore the potential of MAR in alleviating the groundwater depletion problem in NCP by analyzing the impact of MAR on re-establishing the regional water balance when different recharge measures are taken. An integrated surface water – groundwater model will be developed for NCP using the MIKE SHE code, and calibrated based on data from status quo. The leftover water from SNWDP as well as reclaimed water from the domestic and industrial sectors will be used for MAR in scenarios simulations, where the MAR will be modelled in two approaches through 1) direct pumping and 2) field infiltration. The outcome of this research will give a first insight into spatially explicit regional scale modelling to quantify the water balance including both SNWDP and MAR, and will provide an assessment on to what extent MAR can contribute to solving the water scarcity problem in NCP.

Code of abstract: T2.4.11
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Simulation of Managed Aquifer Recharge through Infiltration via Yufu River Channel Bed in Jinan

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KEY WORDS - Managed aquifer recharge; spring restoration; disconnected losing river; intermittent recharge

ABSTRACT
Water infiltrated from river channels is an important source of recharge for the springs of karst aquifer system in Jinan area, Shandong, China. Above the karst aquifer, impervious shale formations limit recharge, although there are also unconsolidated sediments that could be used to increase groundwater recharge. A section of a disconnected losing river, the Yufu River, is being manipulated to increase groundwater recharge to restore the springs. Beneath the upper reaches of the Yufu River is a double-aquifer system with excellent permeability. The upper aquifer is consisted of sand gravel that a high hydraulic conductivity (K1) of 20 m/d, while the lower aquifer is consisted of limestone with a hydraulic conductivity (K2) of 7.29m/d. The shale formation underlain the lower reaches of the Yufu River is much less permeable. Under such geologic setting, it is necessary to regulate the flow in the upper reach of the Yufu River to increase recharge to groundwater. This study aims to evaluate the influence of the surface water velocity and the depth of groundwater level on the volume of recharge through the river channel in the upper reach, which is often dry when the flow is not regulated. Through sand tank model simulation, we found that infiltrated water at first formed perched groundwater, as it continued to infiltrate to the lower aquifer, the water formed two unconfined groundwater levels in the upper and lower aquifers due to the abrupt interface of the two aquifers. The upper groundwater mound is rising as it is being recharged by the river, as it moves downgradient, it further recharges the lower groundwater mound. The movements of groundwater mounds are independent but also interact with each other. The study shows that according to the differences of infiltration mechanism (penetration, leakage, and osmosis) or the initial groundwater depths, a recharge cycle can be divided into 7-8 stages, and the duration and sequence of each stage vary greatly due to the initial groundwater depths and surface water velocities. The surface water flow rate is the main factor affecting the recharge cycle, and groundwater depth is the main factor affecting the duration of each stage in the recharge cycle.

Code of abstract: T2.4.12
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Determination of optimal conditions for minimizing clogging processes occurring during the operation of managed aquifer recharge (MAR) based on lab- and field-scale experiments

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KEY WORDS managed aquifer recharge, clogging, infiltration, lab- and field scale experiments

ABSTRACT
The accumulation of suspended solids and the biomass growth in the soil pore space leads to a reduction of the water infiltration capacity in managed aquifer recharge schemes. The clogging rates depend on site-specific conditions such as soil type, climate, water quality and process-related parameters. The aim of this study was to understand the role and sensitivity of these factors on system's efficiency and to determine the most-suitable conditions for clogging minimization. For this, various real-world MAR operational scenarios were simulated in two physical models at laboratory and field-scale.

The experimental set-up consists of a rectangular-shaped lysimeter installed in the lab (1.5 x 1.0 x 1.0 m) and a rectangular rapid infiltration unit constructed in the field (4.0 x 5.0 x 1.5 m), both filled with sandy soil. The infiltration tests were run using the same water quality (river water with 25 mg/l DOC and 15 mg/l TSS). The ambient conditions were maintained constant in the lab (17 °C and 65% humidity), while in the field the infiltration was conducted under real climate conditions. An array of tensiometers, TDR-probes and suction cups installed in different depths in both systems described the spatial and temporal distribution of soil moisture for all scenarios. The clogging rates were estimated using matric potential and soil water content measurements, as well as periodical tracer tests.

The results from both infiltration units indicate two types of clogging: the rapid clogging of the upper soil layer near the surface, which is strongly influenced by ambient temperature and direct sun exposure, and a slower clogging process occurring within the deeper soil layers, mostly triggered by the quality of infiltrated water. The optimal conditions for clogging minimization differed in the two systems: in the field, a combination of low hydraulic loading rate and a short dry phase provided for the lowest clogging rate, while longer dry phases were responsible for clogging reduction in the lab-scale tank. Nevertheless, scale-specific recommendations for clogging minimization could be provided for each system, which can contribute to a significant improvement of the efficiency of managed aquifer recharge schemes using water of different qualities and running under changing climate conditions.

Code of abstract: T2.4.13
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Development of composite artificial recharge technologies for groundwater conservation and utilization

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KEY WORDS Groundwater, Composite Artificial Recharge, ASR, ASTR, Korea

ABSTRACT
To Considering 10 year drought frequency, regional water supply rate, hydrogeologic condition, groundwater exploitation demand, etc, Imgok-ri area was selected as the pilot test site for composite artificial recharge research area. Since the area is not supplied with regional water supply, and so it is vulnerable to drought, some artificial groundwater recharge technologies will be promising, and stream water (reservoir, wetland), groundwater and mine discharged water may be used for the water supply and recharged groundwater. Based on temperature, fluid electrical conductivity, natural gamma logs and flowmeter, some major permeable intervals of each borehole were identified by geophysical well loggings. Single-well tracer test was performed to evaluate the feasibility of ASR(Aquifer storage and recovery) type artificial recharge at the well SPW-1. Radial convergent tracer test at SPW-2 and step injection test at SOB-2 were performed to evaluate the feasibility of ASTR (Aquifer storage, transfer and recovery) type artificial recharge. According to the results of numerical simulations, we may conclude that groundwater storage in the study area will be recovered significantly with the proper artificial recharge management.

Code of abstract: T2.4.14
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Estimation of the Ratio of Groundwater Recharge to Precipitation Using Time Series Models and Water Table Fluctuation Method

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KEY WORDS Recharge, Time series model, Water table fluctuation

ABSTRACT
Estimation of groundwater recharge ratio to precipitation (RTP) is a challenging but important task for the sustainable use of the groundwater resources. A water table fluctuation method (WTF) is an effective technique to calculate RTP when time series data of precipitation and groundwater level are available. However, missing or abnormal data and effects of pumping and stream water fluctuation close to the groundwater observatory can deteriorate the accuracy of the groundwater estimation based on the WTF. In this study, we designed a method to estimate the RTP using machine learning based time series models and hybrid WTF to solve the limitations. The designed method was applied to groundwater level data of 241 observatories in South Korea, to estimate RTP on a yearly basis. The average and median values of the RTPs for 241 observatories are 15.9% and 10.9%, respectively. We suggested a safety factor for a sustainable use of groundwater resources using a ratio of 1st quantile to 3rd quantile of RTP. The average and median values of the safety factors for the 241 observatories are 0.68 and 0.70, respectively.

Code of abstract: T2.4.15
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Artificial injection test with infiltration galleries setup at the water curtain cultivation area in Jurassic granite-related alluvial terrain, Cheongju, Korea

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KEY WORDS - water curtain cultivation, infiltration gallery, artificial recharge, injection rate, Korea

ABSTRACT
Water curtain cultivation (WCC) method has rapidly come into wide use in Korean agricultural area since its first dissemination in 1984. The annual use of groundwater for WCC has been estimated to be ranged between 0.54 billion and 0.81 billion m^3, which is equivalent to 32 to 48 % of total agricultural use of groundwater in Korea. However, many of WCC area are recently suffering from shortage of water resources caused by the gradual drawdown of groundwater level during the WCC peak season. To solve this problem, several artificial recharge techniques were applied to some WCC areas including this study site. In this study, infiltration gallery system was used. The study area is located in the alluvial point bar controlled by meandering Musimcheon stream of Cheongju city in the Jurassic Daebo granite terrain. The geologic columnar sections of a drilling holes show that alluvial deposit and weathered part of basement rocks, which can be major aquifers, occur in depth interval from surface to 4.1-5.0 m and 11.7-24.0 m, respectively. Seven galleries (A-G) were set up at each empty space between eight vinyl houses and individual dimension was designed as 50 cm x 300 cm x 50 cm. Installation process includes bed excavation, backfill with gravels and silica sands, and completion of gallery by equipment of piezometer and covering with non-woven cloth. The surface of study area is mainly composed of silt or clayey soil with bad permeability, but just underneath has silt and sand mixtures with lots of gravels and pebbles of different size with pretty good permeability in part. For these galleries, two types of recharge test with stepwise and long-term injection time were performed. And the effectiveness of artificial recharge was individually estimated in each gallery by using relationships between varied injection rates and measured water levels increased through these tests. Those relationships are expected to be employed for estimating the annual rechargeable water quantity flowing again into the aquifer through galleries by natural injection process over the period of WCC peak time. As a result of test, E and F galleries showed the worst and best effectiveness, respectively. The efficiency of gallery system for artificial recharge was shown to be pretty good in general and differs among seven galleries due to different soil geology.

Code of abstract: T2.4.16
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.4. Managed Aquifer Recharge

Adsorptive removal of carbamazepine and diatrizoate on iron oxide nanoparticles packed in sand column simulating managed aquifer recharge

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KEY WORDS MAR; pharmaceutical pollutants; magnetite

ABSTRACT
The sorption-desorption of recalcitrant pharmaceuticals in sand/soil columns can be used to infer performance of managed aquifer recharge. Removal of carbamazepine (CBZ) and diatrizoate (DTZ) from synthetic wastewater, containing 100 μg/l of each, was studied in keeping recirculating flow throughout sand columns amended with uncoated or methacrylic acid (MAA) coated magnetite nanoparticles. Removal efficiency of CBZ and DTZ for MAA-magnetite (i.e. 68.34% and 61.91%, respectively) were much higher than that for uncoated magnetite (i.e. 53.47% and 50.26%, respectively). The concentrations of dissolved organic carbon (removal efficiency between 42.28% and 50.08% for the 1st day) were rapidly decreased throughout the soil passage regardless of type of media e.g., sand or NPs, and then gradually increase implying that adsorption-desorption dynamics and competition for sorption sites have taken simultaneously. Core-level binding energy and charge analysis for Fe(2s) and O(1s) obtained by X-ray photoelectron spectroscopy suggests the dominant involvement of physisorption process of solutes on the NP surfaces taken place.

Code of abstract: T2.5.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

A method for separation of heavy metal sources in groundwater using XRF profiles and hydrogeochemical indicators: Fishermans Bend, Australia

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KEY WORDS Heavy metals, XRF, source separation, urban renewal, legacy contamination

ABSTRACT
In Victoria, the largest urban renewal project in Australian history is currently underway close to Melbourne's city centre. The Fishermans Bend urban renewal began in 2012, and heavy metals are significant contaminants of concern in the soils and groundwater, specifically, arsenic, cadmium, chromium, copper, lead, nickel and zinc. Two major sources of metals in groundwater have been identified, namely contaminated fill material, and migrating plumes of landfill or industrially impacted groundwater. A method for separating these metal sources in groundwater has therefore been developed, to help practitioners determine where individual site contamination is sourced from; ultimately better informing liability assessments and remediation options.

A hand-held x-ray fluorescence (XRF) device was used during drilling and installation of 36 boreholes across Fishermans Bend to measure heavy metal concentrations in the fill material and soils at approximately 20-50 cm depth intervals. Groundwater sampling was undertaken using a low-flow pump placed in the middle of the screened interval. Groundwater quality parameters were monitored continuously to ensure representative aquifer water was collected.

A range of indicators were then used to develop the step-by-step method for source separation, based on the lithological (XRF), geochemical, and hydrogeological data. Using the method, groundwater from seventeen boreholes show strong evidence of groundwater metal contamination from fill material via leaching. Evidence includes matching soil and groundwater metal profiles, leaching ratios below a calculated threshold, and significant metal detection by the XRF in the fill material. Conversely, groundwater from nine boreholes show strong evidence of additional metal contamination from landfill and industrially affected groundwater, with evidence including dissimilar soil and groundwater metal profiles, leaching ratios well above the calculated threshold, and minimal metal detection in the fill material. This research indicates that legacy contamination from landfill and former industrial sites at Fishermans Bend will need to be carefully considered in light of the planned urban redevelopment in the area.

Code of abstract: T2.5.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

A sensitivity analysis of the impacts of climate change on groundwater recharge in low storativity fractured-bedrock aquifers in Ireland

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KEY WORDS Climate Change, Groundwater recharge, Irish hydrogeology

ABSTRACT

As well as meteorological factors, the geological properties of a region also influence groundwater recharge rates. In the Irish context, there are two main geological features that limit groundwater recharge. Firstly, a significant part of the island is covered by glacial tills, so the permeability and thickness of this type of subsoil are a major control on the infiltration rates to the underlying bedrock aquifers. Secondly, two thirds of the country is underlain by aquifers classified as 'Poorly Productive'. In these aquifers, groundwater flow is constrained by the properties of the fracture network and results in a limited throughput and storage capacity. These characteristics have influenced the approaches used to calculate groundwater recharge, so a methodology has been developed that accounts for these hydrogeological features in the Irish context. A set of recharge coefficients has been determined based primarily on the properties of the till cover, especially its hydraulic conductivity and thickness. These recharge coefficients are applied to the hydrologically effective rainfall (total rainfall minus actual evapotranspiration) to calculate potential recharge. Then, for those aquifers with low storativity, a recharge cap is applied to represent the limited capacity to accept recharge. This methodology has been applied to carry in a sensitivity analysis for three Irish catchments with different hydrogeological settings to: (1) assess the possible impacts of climate change, and (2) determine how bedrock properties affect the response of these aquifers to present and future recharge. The sensitivity analysis included meteorological variables such as rainfall amount, its intensity and seasonality, but also hydrogeological variables such as the recharge coefficients and recharge caps cited above. The results to date suggest that the effect of changes in climatic variables is strongly influenced by the local hydrogeological settings. This would lead to an unequal impact of climate change across the country depending on the local settings.

Code of abstract: T2.5.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Combining hydrochemistry and remote sensing for a better understanding of groundwater fluxes in Northern Chad

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KEY WORDS Nubian Sandstone Aquifer System, stable isotopes, remote sensing, recharge, water management

ABSTRACT

The Sahara Desert extends over the Northern territories of Chad. The region contains large water resources, above all the fossil Nubian Sandstone Aquifer System (NSAS). The limits of the transboundary NSAS are defined in Chad by two orographic entities which collect increased rainfall: the Tibesti volcanic complex with its highest peaks at 3'445 m located in the North-West, and on the East, the Ennedi mountains reaching 1'300 m altitudes. Further North, the NSAS is connected to the Kufrah basin of Libya, where intensive extraction has been occurring since end 1990's. Here, deep drillings have improved the knowledge of the aquifer stratigraphy, therefore the estimation of reservoir volumes. In Chad, the understanding of this part of the aquifer system remains very uncertain and the remoteness of the region has prevented systematic direct observations of climatic variables and groundwater fluctuations.
The aim of this work is to present a synthesis of groundwater recharge, age and flow paths from the NSAS and the neighbouring mountain ranges, by the interpretation of chemical and stable isotopes signatures performed on 180 water points, collected between 2013 and 2016 and distributed over an area of 88'000 km^2. To relate these data to climatic forcing functions, we employed multiple remote sensing products (FEWS-NET for rainfall data, LandSat8OLI for actual ET estimation and GRACE data for total water change) over the period 2000-2016, and computed a simplified surface water balance for the region.
The resulting conceptual model shows that recharge of the aquifer by recent meteoric water is occurring, but at low frequency. The chemistry of springs, oasis, ponds, and wells/boreholes from the mountainous regions shows distinctive meteoric origin, with main composition of Ca-Mg-HCO3 and isotopic signatures close to current meteoric δ^2H and $\delta^{18}O$. Groundwater and surface water from the NSAS show, on the other hand, a chemical composition generally enriched with Na-Cl and SO_4 and depleted isotopic signatures, compatible with a Pleistocene recharge, as demonstrated by a number of authors in other parts of the aquifer (Egypt, Sudan or Libya).
The implications of these findings in such an arid environment are essentials for sustainable water resources management.

Code of abstract: T2.5.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Comprehensive study of fate and transport of pharmaceuticals in groundwater (PERSIST Project)

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KEY WORDS EOC, groundwater, contamination, antibiotics

ABSTRACT
The presence of pharmaceuticals in the environment represents a great public concern, which reflects recently in numerous scientific publications on the topic. Nevertheless, their transfer and fate in water bodies are not yet well known. Their occurrence has been much better characterised in wastewater and surface water than in groundwater. In this context the PERSIST Project (Fate and Presence of Emerging Contaminants and Multi-Resistant Bacteria in the Continuum Surface Water – Groundwater) aims to increase the knowledge on the behaviour of a selection of pharmaceuticals and particularly, antibiotics. The study was carried out on two complementary field sites: the Vistrenque basin (France) and Empordà basin (Catalonia, Spain) and supported by batch and column laboratory experiments. First an intensive sampling campaign was conducted comprising 54 in Vistrenque basin and 56 sampling points in the Empordà basin. Then, a monthly sampling was performed in representative wells and surface waters, in order to evaluate temporal changes of pharmaceuticals concentration. Further, to refine the conceptual model of groundwater flow system, with an emphasis on origin and residence time, water (^{18}O, ^{2}H, ^{3}H) and sulfate isotopes were analysed. In the Empordà basin, the occurrence of antibiotics is mainly attributed to agricultural fertilization inputs of slurry and manure. Out of 53 antibiotics analyzed, only 14 antibiotics were found with large spatial variability; however, no clear trend of concentration development over time has been observed. In the Vistrenque basin, pharmaceuticals in the water bodies are related to the infiltration of stream water receiving WWTP effluents and are determined by surface water-groundwater interactions. Several compounds (antibiotics, anticonvulsant, beta-blockers and analgesics) were found in surface waters and groundwater. In the laboratory experiments four sediments collected at the field sites were used. We found that biodegradation was small for all the compounds and retardation factors were diversified, depending on compound as well as sediment properties. The data obtained from the laboratory studies will be utilised for developing hydrogeochemical models of the studied areas. The outcomes of the project will help to develop strategies for water management agencies.

Code of abstract: T2.5.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Estimation of the hydraulic conductivity from single dilution tests in the Motril-Salobreña detrital aquifer (SE Spain)

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KEY WORDS single borehole dilution test, hydraulic conductivity estimation, Motril-Salobreña aquifer, vertical flow

ABSTRACT

In this study eight single borehole dilution tests (SBDT) have been carried out in two wells (54 and 25 m deep). The aim has been to determine the hydraulic conductivity (K) to calculate the groundwater flow in a very influential sector of the coastal detrital Motril-Salobreña aquifer since it would be an area where there are several fundamental water inputs. The discharge of a tracer (sodium chloride) in these two wells and its subsequent washing, allow us to determine the apparent rate of dilution of the tracer according to the method of Halevy (1967). Finally this can be related to the Darcy velocity, which will allow us to calculate K.

The rapid washing of the tracer (3 h for one test and for the other, at 4 h only 10% tracer remains) indicates the high values of hydraulic conductivity. The section selected for the calculation of K has a width of 111 m and an average depth of 36 m. The hydraulic gradient has been calculated from the water table measurements taken continuously in both wells, yielding values ranging from 0.0082 to 0.0097, according to the different moments in which the tests were performed. From these data a mean value of hydraulic conductivity of 150 and 365 m/d respectively is obtained for both wells.

The dilution profiles found for both tests are very different. In one of the wells a gradual dilution process occurs at all depths measured and in the other, however, the dilution process could indicate the presence of upward vertical flows that would cause tracer movement not only horizontally but also vertically. In the latter case, the values of K obtained (150 m/d) would be underestimated. The analysis of the groundwater temperature profiles recorded in the SBDT wells confirms the presence of ascending vertical flows in one of the wells. Therefore, it is considered 365 m/d as the most representative value of K in the studied sector of the aquifer.

Code of abstract: T2.5.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Exploring and managing deep-seated groundwater reserves in the Northern Kalahari Basin, Namibia

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KEY WORDS semi-fossil groundwater, renewable, groundwater management, Kalahari Basin, hydroisotopes

ABSTRACT
Unlike fossil groundwater reserves, semi-fossil aquifers are still part of the hydrological cycle and hence, partially renewable. Exploring and managing these aquifers presents a particular challenge as the hydrogeological setting is often complex and both the paleoclimatological and the recent recharge mechanisms are difficult to assess. In Africa, intracontinental basins are known to host deep-seated aquifers providing large volumes of freshwater. Within the northern Kalahari Basin in southern Africa, a deep semi-fossil sedimentary aquifer is developed in the Eastern Zambezi Region (Namibia) approx. between 17°30' -18°30' S latitude and 23°15' - 24°15' E longitude. The confined aquifer referred to as the Lower Kalahari Aquifer (LKA) covers an area of c. 2,100 km^2 and is found at depths of between 120 - >250m. The regional climate is characterized by a unimodal austral summer rainfall regime (MAR 600 – 700 mm). The peculiarity of the hydrogeological conditions of the area resides in the fact that the Zambezi Region is located within an incipient rift system extending in NE-SW direction. The ancient and recent extensional tectonic activity is associated with the propagation of the East African Rift Zone. It controlled the river evolution as well as the development and desiccation of vast paleo-lakes in the Makgadikgadi subbasin.
In this study, we combine an extensive literature review on the paleoclimatological and geological conditions in the Kalahari Basin with geophysical surveys and hydrogeological, hydrochemical and hydroisotopical investigations in order to gain better insight into the flow and recharge processes of the study area. The LKA is bound to the north and south by horst and graben structures. It is suggested that the LKA - prior to tectonic subsidence and burial – was part of a paleochannel of the upper Zambezi River that was located to the west of its modern course. Comparison of stable isotope contents of the LKA with modern rainfall indicates that the recharge occurred under cooler climate conditions, hence presumably during the Pleistocene. Although, the hydraulic gradient is very low (≈0.07‰), hydrochemical data show a distinctive geochemical evolution along the presumed flow path. It is assumed that an apparently brackish groundwater body is undergoing "freshening" in southward direction.

Code of abstract: T2.5.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Investigation of Vibration Effect on Double-Porosity Soil for Non-Aqueous Phase Liquid Migration

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KEY WORDS - Vibration, Groundwater Contamination, Liquid Migration, Aggregate Kaolin, Image Analysis Method

ABSTRACT

Natural disasters and climate change such as earthquake, El-Nino, tsunamis and water pollution had a negative impact on human health and living environment. These occurrences have drawn attention to the vibration and groundwater pollution effect on double-porosity subsurface system. The more complicated situation was that the underground storage tanks and petroleum pipeline damages has caused the leaked non-aqueous phase liquids (NAPLs) to migrate into the groundwater resources. The speed and phenomena of the migration of NAPL into the subsurface system would be more intricate under the effect of vibrated double-porosity soil. These problems need to be addressed by both professionals and researchers worldwide to ensure the sustainability of groundwater utilization. This paper aims to investigate and understand the NAPL migration in vibrated double-porosity soil. To do so it was necessary to study the phenomena and characteristic of soil structure, and the pattern of NAPL migration to identify the cost-effective remediation schemes. A laboratory experiment was conducted to study the phenomena and characteristics of vibration response and NAPL migration in double-porosity soil deformation under vibration effect by using digital image processing technique (DIPT). This study proposed a new model concept with the soil that overlaps the three continuums of fracture porosity, primary porosity, and secondary porosity features. The fracture porosity continuum developed through the effect of vibration had caused the double-porosity soils to cracks. Concept of the double-porosity soil demonstrated two different porosity scales and two distinct sub-regions with contrasting hydraulic conductivity due to different pore size characteristics. The experimental setup and the acrylic circular soil column showed similar effects by using an economical vibratory table, as compared to when using a shake table. To ensure that the vibratory table functioned well and could produce the same reliable data as the shake table, the vibratory table frequencies must be calibrated by using a high sensitivity accelerometer together with Dewesoft Sirius System data-logger to check and obtain excitation frequency for the vibratory table. The fractured double-porosity soil in circular acrylic soil column was used to observe and monitor the NAPL migration through the soil sample with the purpose to have comprehensive understanding of the pattern of groundwater contaminate. Outcome of the experiment indicate a maximum soil surface acceleration at 1.52g and the lowest soil surface acceleration at 0.44g, with the maximum soil surface acceleration (MSSA) observed to be in the middle of the vibration table excitation frequency range. The pattern and relationship could be seen increased in relation to table acceleration and the maximum table acceleration (MTA) value was 2.33g. Thus, the gradual increase of vibration table excitation frequency yielded different vibration responses from the respective soils. This indicated the soil surface acceleration depended significantly on the soil conditions, soil water content, soil structure and the pattern of soil crack. The pattern of crack geometry displayed was hairline crack in soil sample and exhibited flake-grained structural pore orientation. It was shown that hydraulic conductivity and water storage process for a physical behavior correlated with a fractured soil are significantly different from intact soil based on the previous mentioned literature. NAPL migration was faster in sample 2 with 150ml toluene because of the higher amount of toluene compared to sample 1 with 70ml toluene and this could because of the greater capillary force exerted by the toluene pressure on top of the soil sample that had yet to migrate through the sample surface. During experiment, air bubbles were continuously observed at the surface of reducing toluene because of the wettability of the fluids in the soil sample and the air trapped between the fractured aggregate and intra-inter aggregate pores. Both experiments displayed that the NAPL migration reached 100% to the bottom. Finally, it was concluded that the DIPT is capable to provide detailed information, and can be used to understand and identify the remediation method as well as to ensure sustainable consumption of groundwater.

Code of abstract: T2.5.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Investigating groundwater drought and dominant environmental controls with a focus on the drought of 2016 in Sweden

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KEY WORDS - groundwater drought, drought severity prediction, regionalization, classification, Sweden

ABSTRACT
Drought has historically been a minor issue in Sweden, a country of high water abundancy. In the past years the Swedish Geological Survey (SGU) has reported falling groundwater levels through their monitoring program, particularly during the summer in Southeastern Sweden. By the summer of 2016, this problem had intensified and groundwater drought had been registered in large parts of Sweden. The current understanding of the propagation of drought into groundwater for Swedish groundwater systems is poorly understood, hence groundwater drought has been difficult to predict. Here, we attempt to investigate the relationship between meteorological and hydrological drought. This is done by correlation of standardized precipitation index (SPI), standardized precipitation and evapotranspiration index (SPEI) at different lag periods with the recently emerged standardized groundwater index (SGI).With this method the response time of groundwater systems to meteorological drought can be estimated. Further, we can predict both response time and drought severity with multinomial regression models. The two models are based on a number of easily accessible geological (e.g. soil type) and environmental controls (e.g. spatial location), selected in a stepwise routine based on statistical significance. These k-fold cross-validated classification models can thus be used to regionalize drought sensitivity and severity in unmonitored locations in Sweden.

Code of abstract: T2.5.9
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Study of Aqueous and Non-Aqueous Phase Liquid In Double-Porosity Soil Using Digital Image Analysis

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KEY WORDS - Groundwater Pollution, Fracture Porous Media, Saturation, Non-aqueous Phase Liquids, Digital Image Analysis

ABSTRACT

The development activity of the country has played a part in climate change and natural disasters which lead to a negative influence on the geo-environment and health. The issue of leakage and spillage of non-aqueous phase liquids (NAPLs) and aqueous phase liquids (APLs) contribute contamination into the groundwater, resulting in groundwater pollution and rendering the quality of groundwater unsafe for drinking and agriculture. Groundwater contamination is one of the most challenging geo-environmental issues encountered in many countries. More complicated problems arise when the surface or subsurface has experienced earthquake vibration, which probably influences the migration of contaminant into the groundwater sources. Ensuring availability and sustainable management of water and sanitation for all was the goal and target in the 2030 agenda for sustainable development, consisting of a plan of action for people, planet and prosperity of the United Nations. This paper is intended to investigate the aqueous and non-aqueous phase liquid migrations as well as speed rate in the deformable double-porosity soil, which become important for sustainability of groundwater utilisation and a comprehensive understanding of the behaviour of liquid migration into the groundwater. For this aim, an experiment model was conducted to study the pattern and behaviour of aqueous and non-aqueous phase liquid migration in deformable double-porosity soil by using digital image processing technique. A Matlab routine for digital image processing was used to extract area of interest from captured image and to transform the area of interest from distorted image to a scale image via affine transformation method, which involves converting the JPEG scale images to Red Green Blue (RGB) and Hue Saturation Intensity (HSI) images; extracting HSI digital value from HSI image and saving the HSI value in a text file using American Standard Code for Information Interchange (ASCII) format. Surfer software was then used to digitize the control point from reference image to generate map or plot of the migration pattern of dye liquid in fracture porous media using HSI value. Lastly, the contour pattern of dyed liquid migration using the HSI intensity values was plotted. The results of the experiments show that the flow of the APL and NAPL migration was not uniformly downward. The faster migration occurred at the cracked soil surface condition compared to other locations on the soil surface that was not cracked, even not used the same type of liquid such as water and toluene. The migration observation in experiment 1 shows that the dyed water migration was not reach the bottom of the soil column and stopped at 95% downward depth for the deeper migration, while the lesser migration stopped at 22% downward depth of the soil column. This is in comparison to experiment 2, which shows that, overall, the NAPL migration reached 100% to the bottom of soil column. Water has higher viscosity compared to toluene, where the water caused high friction and resistance to gradual migration. This could also be because by the physical bonding between toluene and soil is weaker than water and soil. The physical bonding between toluene and soil was attributed to Van Der Waals Force that are weaker than hydrogen bonding, which have stronger physical bonding between water and soil. This was also one of the reasons why the water migration was slower than NAPL migration. The overall average liquid migration speed rates for experiment 1 and 2 was 0.087 mm/s and 0.112 mm/s, respectively, where the liquid migration speed rate was faster than 0.04 mm/s in the previous research. It can concluded that the factors that significantly influenced the APL and NAPL migration was the structure of the soil sample, fractured pattern of the soil sample, physical interaction bonding between the liquid and soil sample, and the capillary pressure of the liquid. This study indicates that the digital image analysis can provide detailed information to facilitate researchers and engineers to better understand and simulate the pattern of liquids migration characteristics that influence the groundwater resources.

Code of abstract: T2.5.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

The use of hydrogeological assessment for the development of groundwater resource management strategies using the example of the Itawa Springs in Ndola, Zambia

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KEY WORDS Conceptual hydrogeological model, Protection zones, Stakeholder involvement

ABSTRACT

The Itawa Spring is a vital water source for both domestic and industrial users in Ndola, Zambia's third biggest city. In particular, a branch of the national brewery is completely dependent on the spring for water supply. Despite its importance, the spring has come under threat due to land-use changes in its immediate vicinity as well as unregulated growth of settlements downstream, among others. One of the problems the spring faces is on-going erosion due to replacement of native vegetation by crops and a spread of invasive species, which may cause the collapse of the spring and a close-by railway line in the future. Lacking any protection, also the quality of the spring water is at stake due to a variety of possible pollution sources in the spring's recharge area and around the main spring eye. A thorough hydrogeological analysis of the spring was conducted in 2015, serving as basis for the development of future management strategies. The analysis comprised an extensive groundwater sampling and water table measurement campaign. The gathered data on water levels, hydrochemical characteristics and stable isotopes composition gave insights in the age of the spring water as well as potential recharge areas and were used to develop a conceptual hydrogeological model. Furthermore, recommendations of protection zones were derived. Backed by these findings, several steps to protect the spring were developed within a participatory process with multiple stakeholders, including the local community, the brewery and governmental bodies. Steps undertaken or planned comprise the restoration of natural vegetation, the demarcation of protection zones and relocation of households living within the core protection zone, among others. The approach taken demonstrates one feasible option to initiate a more sustainable management of water resources.

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Transmissivity values of pre-Quaternary aquifers based on borehole specific capacity reinterpretation

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KEY WORDS transmissivity, pre-Quaternary aquifers, hydrogeological boreholes, specific capacity, Slovakia

ABSTRACT
Data on pumping tests were interpreted for 6,309 boreholes hydraulically testing aquifers of pre-Quaternary stratigraphy, maintained in a database of the Geological Survey of Slovak Republic. The transmissivity coefficient here was derived from specific capacity by a complex re-interpretation process. Pre-Quaternary aquifer types on the country's territory were divided into six basic groups according to their stratigraphy: (a) Neogene sedimentary aquifers; (b) volcanic Neogene aquifers (both lava and volcanoclastic sediments); (c) sedimentary aquifers of Paleogene age; (d) aquifers in Mesozoic sediments; (e) aquifers in Crystalline and (f) in Paleozoic rocks. Hydraulic parameters of pre-Quaternary aquifers show a log-normal statistical distribution (therefore geometric mean values of transmissivity were evaluated), and also high heterogeneity. Contrary to this, relatively narrow range of mean values of individual datasets: nearly 95% of all mean values of these individual datasets were found in the interval of 0.03 to 1.0 $L \cdot s^{-1} \cdot m^{-1}$. According to this, mean transmissivity values of pre-Quaternary aquifers are also distributed in a relatively narrow interval of one and a half orders of magnitude ($3.0 \cdot 10^{-5}$ to $1.0 \cdot 10^{-4}$ $m^2 \cdot s^{-1}$). An interesting feature was also found when comparing individual basic aquifer types groups (Neogene sediments, volcanic Neogene, Paleogene sediments, Mesozoic sediments, Crystalline and Paleozoic rocks) with ≥ 30 evaluated boreholes and wells. It was found that there is no major difference between Paleogene sediments, Neogene sediments, and volcanic Neogene aquifers, where mean specific capacity is in the range of 0.03 to 0.47 $L \cdot s^{-1} \cdot m^{-1}$ (T values ranging from $4.2 \cdot 10^{-5}$ to $8.2 \cdot 10^{-4}$ $m^2 \cdot s^{-1}$). Mesozoic aquifers show slightly increased values (0.06 to 3.24 $L \cdot s^{-1} \cdot m^{-1}$; $1.1 \cdot 10^{-4}$ to $3.5 \cdot 10^{-3}$ $m^2 \cdot s^{-1}$, possibly due to karstification processes of some Triassic carbonates). Crystalline and Paleozoic groups of aquifers display slightly decreased values (0.02 to 0.04 $L \cdot s^{-1} \cdot m^{-1}$; $4.3 \cdot 10^{-5}$ to $6.3 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$ for standard specific capacity and interpreted transmissivity). With growing population of evaluated boreholes, mean regional values of various pre-Quaternary aquifer types are asymptotically approaching a relatively narrow interval between $3 \cdot 10^{-5}$ to $1 \cdot 10^{-3}$ $m^2 \cdot s^{-1}$.

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Understanding aquifer characterisation to better define sustainable use: Berg River catchment near Franschhoek

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KEY WORDS - Sustainable management, monitoring, conceptual.

ABSTRACT

GEOSS - Geohydrological and Spatial Solutions International (Pty) Ltd – has been involved in groundwater monitoring for a number of farms and estates in the Franschhoek Valley. The area of interest is about 7.5 km south of Paarl and to the east of the Berg River. It is characterised by gently sloping valleys with rugged sandstone mountains to the east and the Berg River to the west. The site location is shown in Figure 1.
The main geology of the area is listed in Table 1 (Council for Geoscience (CGS), 1990, 1997). The area is locally covered by quaternary age (recent) unconsolidated sandy deposits, comprising of alluvium, river terrace gravel and sandy soil. This is likely underlain by the weathered product of the greywacke and phyllite of the Moorreesburg Formation or the granite of the Paarl or Stellenbosch Pluton. Table Mountain Group sandstone forms the rugged mountains to the east. The regional scale geohydrology maps (DWAF, 2001) for the area indicates a fractured aquifer with a yield potential of 0.1 to 0.5 L/s towards the west and a fractured aquifer with a yield potential of 0.5 to 2.0 L/s towards the east. The latter higher yields are associated with the Table Mountain Group sandstone, but the TMG sediments in this area is thin and dry boreholes have been drilled into this formation (GEOSS, 2009). The regional groundwater quality is indicated as good with an associated electrical conductivity (EC) of 0 – 70 mS/m.
The local geohydrology differs substantially from this regional picture. The boreholes on a number of surrounding farms have been monitored for water level and yield. The water level is measured using a pressure transducer that is then converted to water level; the yield is determined using the flow meter and a stopwatch whenever possible. The abstraction from these boreholes is sustainable and much higher than indicated by the regional information. The water level and abstraction monitoring data for production borehole P_Bh03 is shown on the graph in Figure 2 and the location of this borehole is shown on the site map in Figure 3. The borehole yields 6.3 L/s sustainably. The sustainable yield of the other boreholes on the estate varies from 1.75 to 6.3 L/s.
GEOSS has been involved with developing groundwater supply for two new estates and a few of the existing farms in in the area. The sustainable yields of the newly drilled production boreholes on the two estates have been determined using scientific yield tests. The yields determined through these tests are shown in Table 2; these boreholes have been labeled on the site map in Figure 3. A number of boreholes have been drilled towards the northeast of the site and these are low yielding or dry. One of these boreholes were drilled into the sandstone of the Table Mountain Group, but was essentially dry.
A schematic geological cross section is shown in Figure 3 to aid the conceptual understanding of the geology and associated geohydrology. All the P2 production boreholes have been drilled into shale (drilling logs). Borehole PNewBh4 has been drilled into granite. The other two boreholes in this area (P_NewBh1 and P_NewBh3) have been drilled into shale. Borehole P-NewBh1 also shows baked shale with most of the water bearing fractures intersected within the baked shale.
The geology is complex and the geohydrological system is not well understood. It would seem that the water bearing zones of the aquifer are within fracture zones within the shale and or the granite or within the baked contact with the granite. It is not clear why the boreholes within the shale have such high yields. Shale is generally considered to be less favourable for groundwater development because of the argillaceous and incompetent nature of the rock.
Groundwater within the shale has been noted where:

- Shale is overlain by alluvium and the latter provides for improved recharge;
- Fault zones;
- Where more arenaceous units of the shale is located near TMG sandstone and fractures can extend into the shale;
- On the baked contact with granite (Meyer 2001).

The longer term groundwater monitoring in the area has indicated that the local groundwater yield is high. Seasonal variation in the groundwater levels are observed in addition to changes in water level due to abstraction. Groundwater levels recover well after winter rainfall and recharge is clearly occurring. There are a few hypotheses around this local high yielding aquifer. It is possible that some increased recharge is likely as a result of the alluvial deposits associated with the Berg River. However, information from the newly drilled boreholes indicate that a thick (>30 m) clay layer overlies most of the area, with limited surficial cover. There are two different granite plutons mapped and it is likely that there are several different phases of granite intrusion that could likely have resulted in various phases of contact metamorphism and related increase in fracturing. The Saldanian Orogeny caused deformation of the basement Malmesbury rocks, but continued until after the intrusion of the Cape Granite Suite (Meyer, 2001). The related deformation could have resulted in the increased fracturing and water bearing capacity of the Malmesbury sediments as well as the granite. It is also postulated that these fracture zones are laterally extensive and water is transferred from areas distant from this actual study area.
The question that always needs addressing with regards to sustainable groundwater use is related to the recharge. The existing high yielding boreholes have been monitored for a number of years and this has indicated that these high yields are sustainable. The value of the monitoring is clear. For the newly drilled boreholes, the same groundwater monitoring will need to be instituted. In addition the study should be expanded to include isotope studies to attempt to define the actual recharge area.

References

CGS (1990). The 1:250 000 geological map series. Map number: 3318 Cape Town.
CGS (1997). The 1:250 000 geological map series. Map number: 3319 Worcester.
DWAF (2001). The hydrogeological map series of the republic of South Africa. Cape Town, 3318. Scale: 1:500 000.
GEOSS (2009). Geohydrological assessment of the farm Hartebeeskraal, Western Cape. GEOSS report no G2009/11-01. GEOSS - Geohydrological & Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.
Meyer, P. S. (2001). An explanation of the 1:500 000 General Hydrogeological map Cape Town 3317. Department of Water Affairs and Forestry, Pretoria.

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Topic: T2. Sustainable Management of Groundwater Resources
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Groundwater-energy-food nexus for sustainability

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KEY WORDS - water-energy-food nexus, sustainability, water nexus ratio, security, trade-off

ABSTRACT
Nexus of groundwater-energy-food is important for security and sustainability in our societies, because there resources have trade-off and conflicts within the stakeholders, and the synergies of the nexus can bring many benefits to the societies. In this study, groundwater-energy-food nexus in Asia-Pacific region were analyzed based on national scale in terms of self-sufficiency and diversity of resources use including groundwater uses or surface water uses. Not only water consumption for energy and food production, but also energy consumption for water transport/production and for food productions are also analyzed as nexus, as well as food consumptions for energy production in Asia-Pacific region. Among the various water-energy-food nexus, different type of nexus exist such as trade-off, interaction, and synergy, depending on the change in quantity and quality of water resources, with difference of environment impacts. Water nexus ratio, which is the ratio of water consumptions for energy/food production to the total water consumption, was evaluated in Asia Pacific regions as well as energy nexus ratio and food nexus ratio.

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Simulation on dynamic regulation of groundwater and study on groundwater depth critical point of soil secondary salinization area in Hetao Plain, Inner Mongolia

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KEY WORDS: Secondary Salinization Area;Hetao Plain; Groundwater Critical Depth; Dynamic Regulation; Unsaturated Zone.

ABSTRACT

Based on the experiment of soil water and salt movement in salt wasteland, we stablished the Soil water-salt transport model to study the saturated and unsaturated zone. With the key regulation factor of groundwater depth, we simulated the soil salt and water change rule by hydrus software during different periods and under different groundwater depth conditions. Though model inverse calculation, the groundwater depth critical value for preventing soil salinization in different periods were determined quantitatively. Here are the simulation results: under 2-3 times irrigation and leaching conditions, march–June(returning salt phase after Spring thawing), Groundwater critical depth 2.4-2.7m ; the beginning of July-the beginning of September, gound water critical depth1.8-2.1m ; the second ten days of September-the second ten days of November, groundwater critical depth1.5-1.8m ; the third ten days of November- the first ten days of march of the following year (salt accumulation phase after Autumn irrigation), groundwater critical depth2.0-2.3m.The Research results provide reference and evidence for soil salinization improvement in the secondary salinization area of Hetao plain thus owning important theoretical and applied significance.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

A method to assess impacts of future potential climate change scenarios on meteorological, edaphic, hydrological and operational droughts in a basin. Application to the Segura Basin (SE Spain).

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KEY WORDS climate change; impacts, droughts; propagation; semiarid region.

ABSTRACT

Water scarce areas frequently suffer important drought periods, which would be exacerbated in the future due to climate change. An exhaustive knowledge and analysis of the historical and future potential droughts and their propagation can help to design appropriate operation rule for a sustainable management of these water resources systems. In this paper we propose a method to assess impacts of future potential climate change scenarios on meteorological, edaphic, hydrological and operational droughts. We intend to study the propagation and correlation between each kind of droughts within a basin at different spatio-temporal scales. The analysis of drought propagation forces us to employ the same kind of statistical index to assess each type of droughts from the series of variables related with it. For an appropriate analysis of climate change impacts on drought the first step required is to generate the best as possible consistent pictures of plausible monthly future climate scenarios taking into account not only the basic but also the drought statistics of the series. Several techniques will be explored and the sensitivity of the results to them, not only in term of meteorological but also other types of droughts, will be analysed. The climatic series will be also employed to generate future series of streamflow and humidity by feeding with them previously calibrated hydrological balance models. The outputs of these models allow us to assess future hydrological and edaphic droughts respectively. Finally, a previously calibrated water resources management model of the basin can be also employed to analyse impacts of climate change on operational issues (eg. supplies and deficits in demands, storage in reservoirs and aquifers) by feeding it with streamflow series (deduced from the hydrological balance model) and demands (deduced from a agronomic model) in accordance with the future potential climatic scenarios. From these results we can also define operational drought indices.

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Application of multivariate statistical methods for groundwater management in mining areas.

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KEY WORDS mining operations, management, multivariate statistical methods, open pit, mixing

ABSTRACT
Waters in mining activities frequently are formed by different sources. To evaluate the potential composition of the drained water could be necessary for water management. To define the mixing ratios, a conventional mass balance is often used. But, in a few cases there are some typical problems with water mass balance applications that must be addressed. Thus, to solve those problems its required to apply multivariate statistical analysis technique. This methodology is applied to a mining complex, where is necessary to define the water volume drained from Cenozoic aquifer that the mine must be compensated by artificial recharge to comply with the current regulations. The open pit water of mining complex is the mixing between three end-members: run-off, Cenozoic (CN) and Paleozoic (PZ) aquifers. A regional mixing calculation, from a regional field campaign, allowed estimating the composition of PZ and CN end-members which they have been used later for mixing calculations at open pit scale. Run-off end-member was defined from samples collected in the deep sampling points of a network implemented inside of the open pit. The application of multivariate statistical methods, it has allowed to estimate that, during the hydrological years 2013-2014, 2014-2015 and 2015-2016, the open pit water is composed of 6 to 22% for run-off end-member, 35 to 44% for Cenozoic end-member and 39 to 59 % for Paleozoic end-member. Moreover, the run-off end-member was estimated independently by the curve method giving comparable results. This methodology constitutes a useful tool for groundwater management in sites where it is must be known the contributions from each water input which form a mix, especially in mining operations.

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Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Assessment of present and future vulnerability to pumping in Spanish GW bodies using a natural turnover time index.

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KEY WORDS turnover time, residence time, vulnerability to pumping, Water Framework Directive, climate change

ABSTRACT
The concept of natural turnover time or renewable period in an aquifer is defined as the mean residence time, which can be approached by the storage capacity divided by the mean natural recharge. It is an index that can be useful to assess aquifer vulnerability with respect to pumping. Low values of the index show significant vulnerability even in cases with pumping smaller than the mean recharge. In Spain we find areas with important climate variability where long an intensive hydrological drought may appear, and in these cases pumping can produce significant impacts on the aquifers and the related terrestrial ecosystems. This situation will be exacerbated in the future in accordance with the potential scenarios of climate change.
In this work we analyse the impacts of future potential climate change scenarios on natural turnover time in the Spanish Groundwater (GW) Bodies that are in risk of not achieving the Water Framework Directive (WFD, 2000) objectives taking into account the quantitative status (124 GW bodies). We propose to estimate natural turnover time by combining basic information about total aquifer volume, specific yield, and rainfall-recharge models. Different downscaling techniques and ensemble of the generated climatic series will be employed to define potential future climate change scenarios for the cited Spanish aquifers. They will be based on the historical data and results obtained by simulating with different Regional Circulation Models (RCMs). These potential climatic scenarios will be used as inputs of previously calibrated rainfall-recharge models to assess impacts on future recharge and turnover time. We intend to provide an useful tool to identify at the peninsular Spain which aquifers in risk are most vulnerable to exploitation and how it will be exacerbated in the future in accordance with some potential emission scenarios. The results have been analysed for different aquifer typologies: detrital, Karst aquifers, coastal and non-coastal aquifers, in order to withdrawal conclusions depending on different hydrological and management particularities.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Conditions of protection of Grmić well filed, Bijeljina water supply, Republic of Srpska Bosnia and Herzegovina

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KEY WORDS - drinking water, protection, mathematic modeling, Bijeljina.

ABSTRACT
The biggest well field in the Republic of Srpska is located in the east of this Bosnian entity, near Bijeljina town. It provides drinking water for more than 100.000 inhabitants. Current average pumping rate is 574 l/s. A porous aquifer created in coarse gravels is characterized by huge groundwater reserves, probably the biggest one in the Republic of Srpska.
The porous aquifer is in hydraulic contact with the Drina River and it has provided huge recharge rate during a year. Recharge contribution is estimated on 10% from the annual average precipitations (effective infiltration is about 76 mm).
From the other hand, vicinity of the urban area is an issue of concern regarding drinking water quality. Decades ago there was not constructed sewage system. Waste waters were mostly released directly to the aquifer. Furthermore, the recharge zone of Grmić well field is also well-known as the most important agriculture area in the Republic of Srpska. These facts indicate very complex conditions of the well field protection.
In accordance with it, the protection zones are key tools for dependable long-term water supply from Grmić. Of course, groundwater modeling is an unchangeable tool for solving this task.
The protection zones, in accordance with domestic regulations, are based exclusively on groundwater velocity. Groundwater flow toward a well for 7, 90 and 180 days is a criteria for the determination of the zones of severe (zone I), moderate (zone II) and flexible (zone III) regime of the protection.
A flow model for the task solution is prepared. The Visual Modflow of former the Waterloo Hydrogeological (today Slumberger) is selected as a software package. Unfortunately, restricted quantitative-qualitative monitoring data caused the steady-state flow model. Boundary conditions are mostly recognized as natural (rivers and geological no flow-boundaries) but in some parts (north boundary) also as hydraulic boundary (equipotential line). The geometry of the aquifer is defined according to numerous explorations provided in the past. Vertical balance elements are calculated because there are no field measurements of the evaporation and transpiration. Hydraulic properties of the aquifer were well defined during the pumping tests.
After iteration process the mean model error in 34 observation wells was acceptable, less than 0.15 m. Four simulations for the selected periods were provided. The simulation of the highest pumping rate 903 l/s is selected as the criteria for protection zone delineation. In addition, very conservative transport mode (because steady-state flow model) is prepared, just with the aim to show the direction of potential pollution propagation and to facilitate to local authorities to prepare a protection measure plan.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Numerical Simulation Methods for Groundwater Withdrawal Inversion in the Beijing Plain, China

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KEY WORDS - groundwater withdrawal inversion; the Beijing Plain; groundwater management; FEFLOW; FePEST

ABSTRACT
Beijing city is the capital of China and groundwater is the main source of water supply in the city. In the recent years, the Beijing City is experiencing the problems of water shortage. To cope this problem, the South-to-North Water Transferring Project was carried out since 2014 to ensure the security of water use in the northern cities of China, especially for the Beijing city. Effective management of groundwater is essential in the Beijing plain. So accurate estimation of groundwater withdrawal is of great importance for water resource management. But the estimation error is unavoidable in the most areas all over the world because of many human factors. In this study, a method was proposed to inverse groundwater withdrawal based on groundwater flow model. A groundwater flow model in the Beijing Plain was developed by using a popular finite-element software FEFLOW. Based on the sensitivity coefficients of groundwater withdrawal to the average groundwater level of each administrative county, groundwater withdrawal was adjusted and inversed through artificial trial and error method by matching the simulated and measured groundwater levels obtained from the 111 observation wells in the Beijing Plain. By using the proposed method, the estimated annual groundwater withdrawal in the Beijing Plain was 23.16×10^8 m^3, 21.77×10^8 m^3 and 23.44×10^8 m^3 respectively from 2012 to 2014. Simulated groundwater level was proved to fit well with the measured results in each county after the inversion method, suggesting that the numerical model could be used to simulate the change of groundwater level in the Beijing Plain. The relationship between regional groundwater level and groundwater withdrawal was analyzed in the Shunyi County. The method proposed by this paper could provide decision support for county-based groundwater management in the Beijing Plain.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Optimisation of groundwater resources exploitation in the eastern part of the Czech-Saxon borderlands

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KEY WORDS Transboundary aquifer, water balance, optimisation of water exploitation

ABSTRACT
The main objective of joint Czech-German project is the calculation of the water balance of transboundary aquifer in the region of Saxony. The motivation for this project was repeated extreme droughts in 2014 and 2015 in Central Europe. The lack of rainfall negatively impacted particularly on vulnerable quaternary aquifers and in the shallow subsurface hardrocks aquifer. Decline in groundwater levels in the major sedimentary basins has also been registered. According to current calculations, global warming reflected in the overall water balance in Central Europe an annual loss of 5 mm. With regard to the negative impacts of climate change, deep ground water resources in Czech Cretaceous Basin are becoming for both countries important strategic resource.
The first step was to integrate the geological interpretation of the Czech Cretaceous Basin extending on the territory of Germany. Based on the unified geological data hydrogeological transient model is compiled. His simulations and calculation of static and dynamic groundwater resources is based on several climate scenarios. The model is also able to simulate various landuse scenarios and includes a wide range of demographic and socio-economic development scenarios in both countries. All these factors will have a decisive impact on future water consumption in different spheres of national economy, especially in industry, agriculture. An indispensable part of the model simulations is also assessing the impact of climate change and the related withdrawal of groundwater for water related ecosystems.
In the final stage of work model justify the development of transboundary decision-making tool for the optimal use of groundwater resources in both countries, preparation of adaptation measures and quantify the vulnerability of water resources.
RESIBIL project is financially supported by the Program of cooperation to promote cross-border cooperation 2014-2020 between the Czech Republic and the Free State of Saxony

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.5. Transdisciplinary and participatory approaches in groundwater research and management

Groundwater recharge in semi-arid Sahel: Spatial and temporal patterns

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KEY WORDS groundwater recharge, flood mapping, Sahel zone, technical cooperation

ABSTRACT

Groundwater is one of the main water resources in the Sahel region where water supply of a growing population is endangered by recurrent droughts and the impacts of global warming. Uncontrolled water extraction draws groundwater from aquifers in the extensive sedimentary Chad and Iullemmeden basins. However, knowledge about the amount, nature and the spatial patterns of present-day groundwater recharge is only fragmentary and local.
The Federal Institute for Geosciences and Natural Resources (BGR) supports the regional authorities on surface water resources, the transnational commissions of Lake Chad Basin (LCBC) and Niger Basin (NBA), on the establishment of monitoring networks and the development of transboundary groundwater management strategies.
Within the framework of a technical cooperation project, the present GIS and remote sensing-based approach delimits potential recharge areas and estimates groundwater recharge for pilot zones of the Chad and Niger basins. Time series analysis of the Landsat archive (1984-2016), provide a representative spatio-temporal pattern of flood recurrence and seasonality for the last 30 years and allows delimitation of permanent and seasonal water bodies. The information on potential groundwater recharge areas is combined with further parameters controlling recharge: Meteorological information including rainfall patterns and evapotranspiration and infiltration characteristics based on soil data and land use types.
Limited by data availability, data quality, and restricted spatial coverage, different approaches to estimate groundwater recharge are compared and evaluated regarding their suitability and performance in semi-arid regions. The methodological approach and groundwater recharge maps are presented for pilot zones in the Niger and Chad basin and the transferability of the methods to other areas is discussed.

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Water planning and management in the lower Cornia valley by means of advanced modeling tools

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KEY WORDS LIFE REWAT, lower Cornia valley, conjunctive use, saltwater intrusion, H2020 FREEWAT

ABSTRACT

Since the middle of the 1950s, the Olocenic alluvial aquifer of the River Cornia coastal plain (southern Tuscany, Italy) has been progressively exploited for drinking supply, irrigation, and industrial uses, thus causing a remarkable potentiometric drawdown (up to 12 m inland), water balance deficit (about 8 Mm^3 from the 70s to 2001), subsidence, reduction of groundwater dependent terrestrial ecosystems, and the occurrence of seawater intrusion. Therefore, an urgent intervention is necessary in order to restore qualitative and quantitative imbalance of the impacted aquifer.

Within the LIFE REWAT project (sustainable WATer management in the lower Cornia valley through demand REduction, aquifer REcharge and river Restoration; http://www.liferewat.eu/), this is achieved through developing a participated strategy for integrated water resources management at sub-catchment level. Such strategy aims at rebalancing the complex system of the lower Cornia valley in terms of water budget, through optimizing water consumption and increasing intentional infiltration rates. To achieve this objective, five demonstration measures are foreseen: (1) setting up a Managed Aquifer Recharge facility; (2) river restoration of a Cornia river reach; (3) water saving in the civil water supply sector; (4) water saving in agriculture; (5) reuse of treated wastewater for irrigation.

These demonstration interventions are supported by hydrogeological modelling activities through the application of a Geographic Information System and advanced modeling tools integrated in the FREEWAT platform (developed within the H2020 FREEWAT project - FREE and open source software tools for WATer resource management; Rossetto et al., 2015). FREEWAT is a free and open source, GIS-integrated modelling environment which provides spatially distributed and physically based codes (e.g., MODFLOW and USGS-family codes) for the simulation of the hydrologic cycle. The model developed is based on a conceptual representation of the local physical conditions and it allows to: (i) simulate groundwater availability over the last decades; (ii) assess issues related to salinization and water quality, (iii) evaluate water consumption for agriculture purposes, and (iv) manage the demonstration pilot design and operation.

The model is built on a spatial domain 17.0 km x 18.6 km large, using a dynamic process by which, starting from an initial grid based on 200 m x 200 m large cells, the investigated domain is further refined and new elements are added as soon as new data are gathered. Data implemented are related to surface water and groundwater hydraulic head, detailed riverbed bottom profiles, hydrodynamic parameters, depth of aquifer bottom assessed by both existing boreholes and passive seismic measurements, water quality data. The final model is achieved with cells 50 m x 50 m large and detailed information on surface water bodies/aquifer interactions are input. The main outcomes expected are related to the analysis of conjunctive use of ground- and surface-water and the assessment of saltwater intrusion.

The model allows to plan scenarios of rational exploitation of groundwater resources and to set the stage for a governance process (Basin Contract) aimed at sharing a long medium term strategy for water planning and sustainable water management in the lower Cornia valley.

Acknowledgements
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The FREEWAT project has received funding from the European Union's HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.

References

Rossetto, R., Borsi, I., Foglia, L. (2015) - FREEWAT: FREE and open source software tools for WATer resource management, Rend. Online Soc. Geol. It., Vol. 35, pp. 252-255, doi: 10.3301/ROL.2015.113

Code of abstract: T2.6.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

A Cultural Theory of Groundwater Risks and Social Responses in Rural Kenya

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KEY WORDS - Water services, institutional change, risks, business model, Kenya

ABSTRACT

Rural water risks are manifold and complex. Around 200 million people in rural Africa rely on locally managed handpumps for their water supply. Handpump failures often result in extended service disruption leading to high but avoidable financial, health, and development costs. Which risk factors influence rural water users to either manage their groundwater infrastructure themselves or to sign up for a professional service? Drawing on cultural theory, this paper examines environmental, operational, financial and institutional risk factors influencing rural water users to switch institutional arrangements. Four such arrangements are identified: community management with a risk-sharing approach; individual ownership, where risks are internalised; bureaucratic systems, where rules reduce risks; and entrepreneurial models, where risks are used as opportunity. Specifically, the paper focuses on factors that trigger communities to switch from community management to the entrepreneurial model where a small business is providing maintenance service provision within three days from breakdown. Drawing on a unique longitudinal dataset of 3,500 households in Kwale County, Kenya, a water-point mapping survey of 534 handpumps as well as unique observational data from monitoring volumetric handpump usage for one full year, the study finds sign-up for the entrepreneurial model appears to be determined by a range of operational, environmental, institutional and financial factors. From an operational viewpoint, having experienced the reliable service in advance to sign-up as well as distance to alternative sources are significant factors. Low salinity levels appear to be a determining factor on the environmental side. Instead of only having a committee, having spare parts stored at the pump is a significant institutional management factor. Women on the committee is also significant. From a financial angle, those communities that have a system for regularly collecting finance are more likely to sign up for the maintenance business. Private models are increasingly prominent in the rural water sector, hence understanding the factors that drive institutional change is crucial – especially for achieving progress towards reliable services for all as outlined in the Sustainable Development Agenda.

Code of abstract: T2.6.2
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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Challenges and consequences of groundwater development in Turkey: Perspectives on implementation of the EU-water framework directive and the sustainability concept

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KEY WORDS - ecohydrology, development, groundwater, sustainable yield, sustainable management

ABSTRACT
Groundwater resources that occur mainly in alluvial and karstic aquifers account for about 18 % of the calculated water resources potential of Turkey. About 61 % of the groundwater resources potential has been developed, mainly in alluvial plain aquifers, where surface waters such as wetlands, lakes and rivers are important components of the hydrogeological system. Having the water balance approach as basics of calculation of the groundwater resources potential and the "safe yield", determination of the water balance components at certain accuracy has been the main challenge. A certain percentage of the recharge is taken as the basis for the safe yield. The complicated nature of recharge process and the lack of appropriate hydro-meteorological observation network are the two main reasons for the high uncertainty of the recharge estimations. In this approach the aquifer is regarded as a reservoir ignoring the role of the hydraulic characteristics and the boundary conditions. The practice of groundwater development in Turkey based on this simple approach has resulted in significant declines of groundwater levels, over-droughts, quality degradation, dried-out springs and streams and loss of wetlands. Efforts to adapt the Water Framework Directive of the European Union (WFD) to Turkish legislation was very welcomed by the technical water community. The main logic behind the WFD is that water resources can and should be managed as isolated systems, but they are all interacting systems. This approach affirms the concept of sustainability. However, the concept sustainability used with two related terms. Sustainable yield or sustainable use of a groundwater system is the same with its sustainable management; the former being related to sustainability of the use of the aquifer in the expense of degradation of the interacting adjacent systems whereas the latter requires to maintain the interacting systems while the groundwater is utilized. In this paper, taking the practice of groundwater development in Turkey as a representative example for most countries, discusses the problems and challenges that limits the success in implementing the WFD and revisits the concepts of sustainable yield and sustainable management on the basis of hydrogeological and ecohydrological approach, giving some examples form Turkey.

Code of abstract: T2.6.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Common and different features of Chinese and Italian hydrogeological mapping guidelines

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KEY WORDS hydrogeology, hydrogeological mapping, comparative research, China, Italy

ABSTRACT
The definition of common international guidelines for the compilation of high quality hydrogeological maps has been attempting from the second half of the last century for worldwide hydrogeologists, trying to solve the lack of uniformity among national guidelines due to the various geological-hydrogeological and climatic situations of different countries.
According to this issue, China Geological Survey and Geological Survey of Italy-ISPRA are carrying on cooperative research in implementing 1:50,000 scale hydrogeological survey and mapping at selected sites in both countries. The project intends to develop a new generation of hydrogeological and groundwater resource maps with descriptive effectiveness and consistency to field survey data. The project will promote improvements of technologies in hydrogeological survey and mapping of the two countries and might be even agreed at a wider international level.
Chinese and Italian hydrogeological guidelines have similar aspects as concerns: 1) request of carrying out field surveys at 1:50,000 scale and more detailed scale (1:25000); 2) building of a hydrogeological database; 3) publication of the official map in both paper and electronic form; 4) inclusion of several small scale maps inlayed at the margin of a main map in the hydrogeological map layout; 5) comparable level in required survey quota. Furthermore, more attention will be paid on 3D map, conceptual model, aquifer structure, groundwater cycle and hydrogeological parameter description.
In contrast, the most important difference regards the followings. The hydrogeological mapping guidelines of Italy have integrated specifications for both survey and mapping, i.e. they deal with a structural layout characterized by survey contents followed by mapping contents and reflect a technical route of surveying for mapping. On the contrary, there are no mapping contents in the current hydrogeological guidelines of China and it is then needed to be formulated. The Italian guidelines could provide important references for China in legend organization, mapping rules, survey quota and so on.
Finally, it is of great significance the collaboration between China and Italy, two ancient civilized countries situated in "One Belt and One Road".

Code of abstract: T2.6.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Specific vulnerability assessment in karst system, example of Jadro and Žrnovnica springs catchment area, Croatia

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KEY WORDS - groundwater quality, contamination, specific vulnerability, COP, Jadro and Žrnovnica

ABSTRACT
Aquifer vulnerability to contamination assessment is proved to be avery frequent and valuable tool for evaluating the threats which contaminant load poses to groundwater quality, as well as vulnerability maps, which can be used as a background for land-use planning and as an additional tool in groundwater protection. According to the COST Action 620 "Vulnerability and risk mapping for the protection of carbonate (karst) aquifers" there are two types of vulnerability – intrinsic, which deals only with intrinsic characteristics of aquifers, and specific, which takes into account the type of contaminant or group of contaminants, their characteristics, as well as retardation and degradation process which can occur in the interaction between contaminants and overlaying layers.
The Study area includes the Jadro and Žrnovnica springs catchment area which is located near Split, central Dalmatia, Croatia. Both springs are a very important source of drinking water for more than 300 000 local inhabitants. The catchment area, approximately 560 km^2 wide, is predominantly composed of permeable carbonate rocks, which makes it even more difficult to protect groundwater resources. Recent studies have shown that there has been a trend of deterioration in the quality of spring water due to economic expansion in the catchment area and lack of appropriate protection of drinking water sources. The changes in water quality are not alarming, but a positive trend of increasing pollution, even below MAC limits, can indicate the existing problems, as well as encourage finding solutions to improve the water quality
In this paper, specific vulnerability will be assessed using COP method in addition to definition of specific parameters S for nitrates, some heavy metals and indicators of microbiological contamination. The results of the specific vulnerability will be compared with the hazard analysis which has already been made for the study area in order to assess the level of anthropogenic impact. The measurement of concentration of some contamination indicators in some parts of the catchment area will be used to evaluate the comparison results. Such a comprehensive study can be used in defining the measures of protection or remediation to preserve the quality and quantity of groundwater as an essential source of drinking water from karst areas.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Making the transition to conjunctive water management

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Conjunctive water management, principles, practices, transition

ABSTRACT
Conjunctive water management involves the combined use of groundwater, surface water and/or additional sources of water to achieve public policy and management goals. Conjunctive water management enables greater water supply security and stability, helps adaptation to climate variation and uncertainty and reduces depletion and degradation of water resources. There are many opportunities to benefit from conjunctive water management when water management arrangements can be successfully tailored to local circumstances and knowledge gaps and institutional and political challenges can be overcome. This presentation reports on results from an international study which aims to develop broadly applicable principles and good practices of conjunctive water management taking account of international differences in water management opportunities and capacity. The study includes the first comprehensive assessment of progress towards conjunctive water management in Australia, based on data from the States and Territories, and initial results of case studies of conjunctive water management from other regions of the world. Conditions for the effective implementation of conjunctive water management have only been partially met by the Australian States. There has been progress towards integrated groundwater and surface water assessment and accounting, but there is little systematic attempt to plan and manage surface water and groundwater storage and use together at a regional scale over time. Current policy settings effectively subsidise surface water storage, and aquifer storage and recovery entitlements are not in place in most jurisdictions. In Australia and other countries a new paradigm of conjunctive water management is required involving systematic consideration of the beneficial integration of groundwater, surface water and other water sources in water plans and projects. Transition to conjunctive water management can be promoted by partnerships including change agents, water management organisations and coordination bodies supported by strong leadership from governments.

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Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Proactive Water Communication by Oil and Gas Operators in Western Canada

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KEY WORDS - Regional, Communication, Hydraulic Fracturing, Baseline

ABSTRACT
The oil and gas industry in Canada prioritizes water resource management through the proactive approach of many industry producers. Baseline Water Resource Inc. (Baseline Water) conducted a regional hydrogeological/hydrological study in the Lochend Industry Producers Group (LIPG) oil and gas operating field northwest of Calgary, Alberta. This study is an example of how landowner concerns regarding potential water quality impacts due to hydraulic fracturing can be addressed cooperatively. The study objective was to characterize regional hydrogeology and provide a baseline of natural variation in groundwater chemistry. LIPG practices include offering landowners pre-drilling quality and quantity (yield) tests on water wells within 400 metres of hydraulic fracturing activity. The study consisted of 323 water well and 29 spring tests throughout the LIPG field. Additionally, long term groundwater quality monitoring was performed at one location for a duration of two years coinciding with oil and gas production. Groundwater from the shallow Paskapoo Formation sandstone aquifer is the primary water source for local landowners. Indicators of potential groundwater impacts from oil and gas activity may include elevated chloride and Total Dissolved Solids (TDS) concentrations or the presence of hydrocarbons. The groundwater quality results were comparable to regional background groundwater chemistry and demonstrate natural variation. The data may serve as a baseline for comparison with future water quality analyses. Results of the long-term groundwater quality monitoring at a single domestic water well indicated no adverse impacts from adjacent oil and gas operations. Study findings were used to prepare communication documents to facilitate water quality discussion between LIPG and private landowners. Stakeholder communication and engagement are paramount to expediting project timelines and improving public perception of the oil and gas industry.

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Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

The Groundwater Game: A Serious Game on Improving Groundwater Management through Cooperation and Collective Action

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KEY WORDS groundwater awareness, stakeholders participation, serious gaming, Sub-Saharan Africa

ABSTRACT
The International Groundwater Resources Assessment Centre (IGRAC) has developed 'The Groundwater Serious Game' (GW-Game) as a tool for raising awareness about groundwater resource. This 'serious game' is based on a computed calculation-sheet in which the players form part of a rural community pumping groundwater to irrigate their crops. The objectives of the GW-Game are to: (i) improve the participants' understanding of the functioning of groundwater systems and introduce technical concepts; (ii) foster a deeper appreciation of the collective action choices and challenges for regulating groundwater use by influencing policies and management practices; and (iii) open up a discussion on the challenges of sustainable and equitable groundwater resources management. The game is played over several rounds following three different development scenarios in which new management features and information are added. At key moments the players are requested to take action and make decisions, first individually and later collectively.
During 2015-16, IGRAC collaborated with 'GroFutures' (the Groundwater Futures in Sub-Saharan Africa project) of 'UPGro' (the Unlocking the Potential of Groundwater for the Poor programme) to trial a version of the game in Sub-Saharan Africa. A series of three test-sessions were played with GroFutures' scientists and two intensive sessions at multi-stakeholder 'Inception Workshops' in the Great Ruaha Basin (Iringa - Tanzania) and the Iullemmeden Basin (Niamey - Niger) with nearly 50 participants (local basin authorities, national government, farmers, community representatives, NGO representatives, graduate students and researchers).
The experience gained during the GroFutures' project has proved that the GW-Game is a very useful tool for opening up a constructive discussion on groundwater management with a diverse group of stakeholders, stimulating critical awareness and serving as an ice-breaker. During the game sessions we observed a substantial amount of interaction among the participants and a high willingness to discuss the pros and cons of different groundwater management strategies. Careful reflection and feedback at the end of the sessions also helped us to learn a lot about the issues in those communities and gave some ideas for further improvement of the GW-Game.

Code of abstract: T2.6.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
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Unitisation – a Community-Based Approach to Aquifer Management

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KEY WORDS Unitisation, Aquifer Management, Water Users Association

ABSTRACT
Unitization, as currently employed in the development of oil and gas reservoirs, is defined by government-mandated single ownership and management of a reservoir or 'field' such that, *inter alia*, it is characterized by the following attributes: 1) develops and operates as a unit; 2) avoids the economic waste of unnecessary well drilling and construction of related facilities that would otherwise occur under the competitive "rule of capture"; 3) minimizes surface use of the land and surface damages by avoiding unnecessary wells and infrastructure; 4) allows sharing of development infrastructure, thus lowering the costs of production through economies of scale and operating efficiencies; 5) maximizes the ultimate recovery , according to the best technical or engineering information; and 6) gives all owners of rights in the common reservoir a fair share of the production. The concept was developed in order to avoid a repetition of the situation that developed in the late-19th and early-20th century oil and gas industry, where intensive exploitation of reservoirs led to premature depletion and, in some cases, irreversible damage to their storage characteristics. In aquifers, likewise, the practice of excessive, uncoordinated and or unsustainable abstraction, and related water-table or potentiometric-surface drawdowns, creates similar problems of long-term storage destruction and environmental impacts. Two case studies are presented from South Africa, namely, a) the Palaeozoic fractured-rock system in the Klein Karoo Artesian Basin and b) the Late Cenozoic coastal primary system around Stanford in the Western Cape, to illustrate the advantages of application of the groundwater 'resource unit' concept. A key element is the governance approach to the licensing of an aquifer unit rather than individual borehole abstraction under provisions of the National Water Act of 1998, which can be facilitated via the establishment of a voluntary Water Users Association (WUA) or a Water Services Intermediary (WSI) as private services provider. To the extent that the local South Africa approach resembles, but yet may differ from unitization as indicated by the above-mentioned attributes, it probably needs to evolve further in the latter direction.

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Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Indicator based approach to prioritise transboundary aquifers at risk from development stress, pollution or climate change.

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KEY WORDS - transboundary, indicators, dependence, risk

ABSTRACT

The recently concluded Groundwater component of the Transboundary Waters Assessment Programme (TWAP Groundwater) used 10 core indicators and 10 additional indicators to provide a comparative assessment of 199 transboundary aquifers across the world. One of the aims of this programme was to prioritise transboundary aquifers for future interventions. Data to compile these indicators were collected from national experts via questionnaires and from a global water use model (WaterGAP by Goethe University Frankfurt). Data on transboundary aquifers are scarce and difficult to obtain, which meant there were considerable data gaps in the TWAP Groundwater assessment. This led us to develop a modified approach using less and slightly modified indicators to define which transboundary aquifers are at risk. The proposed method has been applied using the TWAP Groundwater dataset for transboundary aquifers, but it can be applied to national aquifers alike.

The method operates on 'progressive exclusion' based on importance of groundwater to human development and to ecosystems and risks related to depletion and quality degradation. First the (national segments of) aquifers are selected for which there is a high human dependency on groundwater and/or with a high dependency of ecosystem on groundwater. These aquifers which are currently important to humans and ecosystems are then further categorised based on groundwater development stress and groundwater quality, which results in 'important aquifers' with high risks under current conditions. Similarly the important aquifers are categorised on their vulnerability to climate change and pollution which results in a selection of important aquifers with high future risk. Presence of a (transboundary) legal and institutional frameworks completes the assessment by providing an indication as to how well equipped countries are in managing the groundwater resources and dealing with the risks.

The work presented is based on data from the Groundwater component of the Transboundary Waters Assessment Programme funded by the Global Environment Facility and executed by UNESCO-International Hydrology Programme with assistance from IGRAC.

Code of abstract: T2.6.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Tackling illegal groundwater abstractions: A must for groundwater governance

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KEY WORDS illegal groundwater abstraction, inspection, accreditation, drilling companies

ABSTRACT

The environmental inspectorate division (EID) is the main inspecting body for environmental legislation in the Flemish region (Belgium). Groundwater-related topics increasingly appeared in environmental legislation over the past decade. The Water Framework Directive (WFD), over abstraction and deteriorating groundwater quality were some of the triggers for the Flemish region to implement additional groundwater legislation. Environmental enforcement is situated on a keystone position translating groundwater awareness from the legislative point of view to the field.
Illegal groundwater abstractions have been inspected by the EID since the beginning of the 90's. Initially these abstractions were randomly encountered during inspections or pointed out by other government agencies or complaints. Generally though they tend to remain below the radar and can only be found through thorough research , e.g. checking of water balances. This loophole in groundwater governance was documented and reported by the EID, together with the results of groundwater inspections over the years. Suggestions were made for additional legislation and installment of an accreditation scheme for drilling companies, as the EID is ideally placed at the end-of-pipe position for the groundwater policy makers. These suggestions were eventually adopted in Flemish legislation and now the EID is coordinating between different inspection bodies to gradually implement a performant scheme for inspecting drilling companies in the field.
One of the keystone tasks of the EID in the future will be to support local enforcement by systematical planning of inspections at smaller scale establishments. This extension of the tasks of the EID will be a benefit to ground water governance in the Flemish region, extending its full reach to the entire scope of groundwater use.

Code of abstract: T2.6.11
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

The European groundwater research and knowledge inventory (EIGR) to enhance societal impacts and multidisciplinarity of hydrogeology: update from the KINDRA H2020 project

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KEY WORDS - Water Directives, Science, Policy, groundwater, societal challenges

ABSTRACT

The H2020 KINDRA project (Knowledge Inventory for hydrogeology research, Grant Agreement 642047, www.kindraproject.eu), funded by the HORIZON2020 Framework Programme, is dealing at European level with research and knowledge in groundwater.
A new terminology and classification methodology on groundwater research and knowledge (HRC-SYS) has been developed by categorizing groundwater research in three main categories: 1) Societal Challenges, 2) Operational Actions and 3) Research Topics. Each of these three main categories include 5 overarching sub-categories. The complete merged list of about 240 keywords, selected from the Water Framework and Groundwater directives and from high impact scientific journals, has been organized in a tree hierarchy. The classification system maps the relationships among main categories through a 3D approach, where along each axis the 5 overarching groups are plotted. To facilitate analysis and report of relationships, 2D representations are possible.
The European Inventory of Groundwater Research (EIGR) is the subsequent tool which applies the proposed classification. The EIGR is intended to be used: i) for insertion of information pertaining to groundwater research and knowledge; ii) for consultation during and after the project by people and organisations dealing with groundwater issues; iii) for analysing collected and stored information to identify trends, challenges and gaps in groundwater research. The classification system allows the comparison of the two "technical categories" with the Societal Challenges identified by Horizon2020, enhancing the multidisciplinary approach and the relationships among science, knowledge and society. The adopted set of performance indicators (classes of research/knowledge, technology readiness level, grants, etc.) are used for an on-going trend&gap analysis.
The EIGR, containing more than 2000 records inserted by national experts of European Federation of Geologists, is now open to external users, who can showcase their research to the community of European professionals actively contributing to the European water sector, by uploading metadata related to a wide range of information sources, ranging from scientific papers, hydrogeological maps, technical reports, book chapters to position papers.

Code of abstract: T2.6.12
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE IN THE PART CONCERNING AQUIFER VULNERABILITY IN THE SAMOBOR AREA

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KEYWORDS: quality, aquifer vulnerability, risk, qualitative status, groundwater body

ABSTRACT

Information about water quantity and quality is the basis for successful management of water resources, particularly under conditions of sustainable development, which itself is the basis of the EU Water Framework Directive (WFD) 2000/60/EC. As part of analysing groundwater quality issues in relation to WFD requirements, it is extremely important to define natural aquifer vulnerability and assess the risks, based on which measures have to be taken in the future to establish good qualitative status of groundwater. Vulnerability is indirectly included in the segment of initial characterization of groundwater bodies, as well as a step to the definition of groundwater bodies at risk. The supply of drinking water of adequate sanitary quality in the Samobor area is based on groundwater intakes, which makes the determination of qualitative water status one of the main parts of water resource management. In this regard, vulnerability of the aquifer in the Samobor area was evaluated using GOD methods. In addition, the results of vulnerability assessment of aquifers and hazards were integrated, which enabled the assessment of the risks of aquifer contamination.

There is also a need to reach a common standpoint about the assessment of vulnerability, hazard and intensity of risks to aquifer pollution in the Samobor area, and a need for mapped presentation of the results.

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Decision Support System for Water Rights Licencing in Alluvial Aquifers

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KEY WORDS groundwater management, water rights licensing, alluvial aquifers

ABSTRACT
Groundwater is one of the Slovenia's most important natural resources. It plays an important role in public water supply and provides about 97% of drinking water. In the Second Slovenian River Basin Management Plan for the period 2016-2021, the ratio of groundwater abstraction (2010-2013) to the mean long term available groundwater (1981-2010) is 3%. From an overall national perspective, the groundwater resources are abundant. But locally, the availability of ground water varies widely. Groundwater abstraction is highest in alluvial aquifers, reaching as high as 26% of available groundwater. The largest pressure on groundwater quantity is in shallow aquifers, located in alluvial plains along main Slovenian rivers, where big Slovenian cities lie and there is a lot of arable land as well. Here, the drinking water abstraction is accompanied with other water uses, mainly with irrigation and industrial use of groundwater. Responsible and sustainable groundwater management is therefore crucial and means co-ordination of interests and rights of those that abstract groundwater already and those who will abstract groundwater in the future. In Slovenia, the granting of water rights (water permits and concessions) is responsibility of Ministry of the Environment and Spatial Planning and Slovenian Water Agency. To help those decision makers in groundwater rights licensing, a complex decision support system, based on modelled groundwater quantities, has been set up. For now, the system is operational for six shallow alluvial aquifers with significant abstraction pressures. The system links the results of numerical groundwater flow models with the water permits and concessions databases and help groundwater managers to quantify groundwater reserves for a given aquifer and provide information about quantity of groundwater for water rights licensing. The quantities of already granted/or to be granted groundwater have to be ensured in any time for several years during the validity of the water rights, therefore the modelled quantity of groundwater represent hydrological situation in the aquifer that ensure sustainable use of groundwater resource. The system enables that the water quantity data from water permits and concessions in conjunction with the results of numerical groundwater modelling are used in the managing process of granting water rights to users in terms of their long-term access to groundwater (sufficient quantity of groundwater) and in relation to the water rights of other users (co-impact of groundwater pumping). Also, groundwater access must be managed in such a way that it does not cause unacceptable local impacts (pumping must not lower the water level for more than 2/3 of water body in the medium-low hydrological conditions).

The goal of the expert decision support system is to provide control mechanisms in order to verify the granting of water rights for the sustainable use of groundwater resources, to prevent overexploitation of groundwater and degradation of groundwater dependent ecosystems and to ensure that the groundwater is available for future generations.

Code of abstract: T2.6.14
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.6. Regulatory framework of groundwater management

Decision Support Tool for the Selection of Suitable Managed Aquifer Recharge Methods

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KEY WORDS - managed aquifer recharge, decision support tool, groundwater

ABSTRACT

Managed aquifer recharge (MAR) is implemented worldwide for various purposes, such as maximization of natural storage, management of water quality, physical aquifer treatment, management of water distribution systems and ecological benefits. Many different MAR methods are available. They are implemented on different scales, under different (hydrological) conditions and for various purposes. The selection of a MAR method is influenced by hydrologic and hydrogeologic factors such as geology, soil infiltration capacity, available water quantity and quality. Further important measures are the available land and cost.

The selection of an appropriate MAR method for given local conditions is key to develop, operate and maintain an efficient and economic MAR project. To assist in the selection of appropriate MAR methods, INOWAS and IGRAC developed an online MAR method selection tool. This tool is based on the classification system developed by IGRAC and part of the INOWAS MAR Decision Support System (INOWAS-DSS). The method selection criteria are based on researched suitability factors and expert review. The tool is validated using 1200 case studies of the global MAR inventory.

Although the selection of an appropriate MAR method is very case specific, the tool assists in providing a first idea about which methods can be applied to a site with certain characteristics. The MAR methods selection tool can assist in the planning or discussion of MAR options in a clear and transparent way. The tool is not designed to replace experts, but rather to rationalize their initial selection process. Because the tool is available online, it can assist in informing stakeholders, such as governments, communities and donors, by illustrating the decision making process.

Code of abstract: T2.7.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Groundwater tritium anomalies in South Africa and their bearing on groundwater recharge estimates

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KEY WORDS Tritium, Groundwater Recharge, Groundwater Sustainability, Karoo Basin, Climate Change

ABSTRACT
In semi-arid to arid regions like southern Africa, demands on groundwater reserves are significant. In order to determine the sustainability of groundwater reserves it is critical to constrain whether the reserve is being regularly recharged by rainfall. Tritium, which has a half-life of 12.36 years, can act as a tracer for this purpose as it is dominantly produced in the upper atmosphere and once isolated within an aquifer will decay at a constant rate. The interpretation of groundwater with detectable tritium activities therefore, is that it is being actively recharged with atmospheric tritium transported into the groundwater system by rainwater recharge. In this study, tritium activities in 277 boreholes distributed across South Africa were used to develop a national model for tritium activity in groundwater in order to establish the extent of modern, ie recently recharged, groundwater across South Africa. The tritium model was combined with modelled depth to water using 3079 measured static water levels obtained from the National Groundwater Archive. The model was validated against a separate set of 40 tritium activities along the west coast of South Africa. The model showed good agreement with the distribution of rainfall across South Africa and this correlation has also been documented globally (Gleeson et al., 2015). However, the arid Karoo basin in the south west of South Africa shows higher than expected tritium levels given the very low regional precipitation rates and low tritium in South African precipitation, typically ~1.5 – 3 tritium units (TU). Measured groundwater tritium values in the Karoo basin exceed 4 TU in many places with a maximum of 4.4 TU. The region of elevated tritium activities coincides with the Karoo Uranium Province and we postulate that there is a link between the two. Understanding this relationship is critical to understanding the natural distribution of tritium within groundwater in South Africa, as addition of tritium from sources other than atmospheric would result in elevated activities and the overestimation of recharge.

Code of abstract: T2.7.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Hydrogeochemical and isotopic characterization of bedrock groundwater in a mountinous area during pumping tests

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KEY WORDS bedrock aquifer, stable isotopes, groundwater age, well test, agricultural activity

ABSTRACT
The study area is a sparsely populated mountainous area with less intensive agricultural activities. The area has crystalline bedrock composed of metasedimentary rocks including limestone and coal layers with low-yielding weathered and fractured aquifers. To assess characteristics of groundwater yield and flow, pumping tests were performed at two test wells in high- and low-altitude areas. Hydrogeochemical parameters and stable isotopes of groundwater were monitored during the tests. The first test well in the high-altitude area showed large variations in concentrations of hydrogeochemical and isotopic indicators which can be attributed to contribution of surface water with the progress of pumping. In contrast, a nearby monitoring well showed little variation during the pumping, which showed high heterogeneity of the bedrock aquifer. Groundwater ages were determined as 20 to 30 years for the pumping well and >50 years for the monitoring well using CFCs and SF_6. The difference in groundwater age is consistent with that in the variation of hydrogeochemical and isotopic indicators of the test and monitoring wells. Groundwater from the second test well in the low-altitude area had higher concentrations of HCO_3 and Cl and showed less variation in concentrations of hydrogeochemical and isotopic indicators compared to the first test well. This indicates that groundwater from the second test well is more affected by both natural and contamination processes compared to the first test well. The second test well also had stable isotopic compositions similar to those of a nearby public supply well implying that groundwater flow system is well connected in the lower area.

Code of abstract: T2.7.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Cause and implication of hydrochemical stratification of CO_2-rich groundwater in a shallow monitoring well, South Korea

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KEY WORDS hydrochemical stratification, CO_2-rich groundwater, groundwater monitoring

ABSTRACT
Cost- and labor-effective monitoring is important to manage the underground source of drinking water (USDW). Groundwater level, water temperature, and electrical conductivity (EC) are commonly used for long-term, automatic monitoring of USDW. These parameters are also monitored in hourly basis at monitoring stations of the National Groundwater Monitoring Network (NGMN) of South Korea. At a NGMN monitoring station at the southeastern part of South Korea, groundwater is characteristically CO_2-rich. A remarkable change of monitored data was observed with increasing depth at the station; in particular, the EC of groundwater showed a significant drop with a stepwise change toward shallow depths. The logging of physicochemical data (pH, water temperature, EC, and ORP) within the well also showed a vertical stratification of water chemistry. Groundwater at shallow depths (< 7 m deep) had low EC values (ca. 280 μS/cm), while deeper groundwater (down to 70 m below the land surface) had the higher EC values (up to 3,900 μS/cm). Hydrochemical analysis of groundwater samples from different depths, in conjunction with the borehole imaging using a nano camera and the mineralogical analysis of suspended particles, indicated that the observed vertical stratification of groundwater is the result of physicochemical changes of CO_2-rich groundwater by CO_2 degassing and subsequent precipitation of minerals such as ferrihydrite upon ascending. Precipitation of ferryhydrite results in significant drop of the concentrations of solutes via sorption. The result of this study suggests that multi-depth monitoring of groundwater is recommended for precise and reliable monitoring of USDW (especially, CO_2-rich groundwater).
This study was supported by the Korea Ministry of Environment (MOE) as “Korea-CO_2 Storage Environmental Management (K-COSEM) Research Program”

Code of abstract: T2.7.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Isotopic characterization of groundwater tapped for drinking use in multilayer alluvial aquifers of Milano and Monza provinces, Italy

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KEY WORDS - groundwater, drinking water, isotopes, EU directives, hydrogeology

ABSTRACT

Management of groundwater resources for drinking purposes requires not only a classical chemical characterization for safety plans, but also the best possible knowledge of aquifer characteristics, recharge area extension and infiltration amount, seasonal and yearly changes in water table and aquifer discharge. A valid conceptual model of the groundwater flow system is a basic element for optimizing groundwater withdrawals, in terms of resource amount and of vulnerability to pollution.

Under this framework, the use of isotope tools is not frequently adopted by regional drinking water authorities. Besides classical water stable isotope studies, analyses of tritium, nitrogen, carbon and sulphate isotopes are proven to be a fundamental tool for contributing to water management strategies in areas affected by human activities. Surface water/groundwater interaction, origin and fate of contaminants, groundwater age evaluation, are some of significant improvements in groundwater conceptual model allowed by isotope investigations.

In order to refine the groundwater flow conceptual model in the Milano and Monza provinces (Northern Italy), an extensive isotope characterization of groundwater was promoted by the CAP Holding Company distributing drinking water. As part of this study, sampling events were conducted in November 2015, April 2016 and October 2016 including more than 100 wells which are tapping groundwater from different depths in the multilayer hydrogeological system of Padana Plain, between Ticino and Adda Rivers. The isotope analysis includes: about 250 stable isotopes analysis in water ($\delta^{18}O$ and $\delta^{2}H$), more than 120 tritium analyses, more than 60 analysis of isotopes, in nitrate($\delta^{15}N$ and $\delta^{18}O$), sulphates ($\delta^{34}S$ and $\delta^{18}O$) and dissolved inorganic carbon (DIC) ($\delta^{13}C$), 26 carbon-14 analysis on DIC and about 20 isotope analyses on chlorinated solvents ($\delta^{13}C$ and $\delta^{37}Cl$).

This study represents probably the largest isotope investigation on drinking groundwater in Italy and it is based on a conceptual model of groundwater flow developed by CAP Holding in previous years. The results of this study will be use to refine the knowledge of the groundwater flow and resource regimen representing a valuable contribution for groundwater management, both at regional and local scale (up to single well management).

Code of abstract: T2.7.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Laboratory study on sorption and biodegradation of selected pharmaceuticals – influence of flow velocity on transport

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KEY WORDS EOC, groundwater, modeling, sorption, biodagradation

ABSTRACT
Occurrence of pharmaceuticals in groundwater has become a great environmental concern. Though, their transfer and fate are not yet well known in water bodies, especially in groundwater. Since biodegradation and sorption are the main processes leading to the loss of contamination in the aquifers, the task of the presented work was to determine these processes of selected pharmaceuticals in selected sediments in well controlled laboratory experiments. In particular the impact of flow velocities on sorption and degradation rates of selected compounds was studied. Column experiments were performed at three different flow velocities, under abiotic and biotic conditions, and applying conservative (bromide, uranine) and reactive tracers (selected pharmaceuticals). Three different sediment types were selected for the experiment: (1) coarse sand; (2) medium sand; (3) sandy loam. Sediments were filled into stainless steel columns. Conservative tracers and compounds of concern were injected into the columns as a pulse. Concentration curves were measured at the columns' outlet. From the tracer breakthrough curves retardation factors and degradation rates were determined and the influence of variable flow conditions on these transport parameters was evaluated. Observed concentrations and recoveries of atenolol and clofibrate were low and indicating strong influence of sorption and degradation on their transport. Diclofenac, caffeine and carbamazepine were also affected by sorption and degradation but to a lesser extent. Sulfamethoxazole, ketoprofen and antipyrine were recovered nearly completely, showing less impact of these processes on their transport. Biodegradation was small for all the compounds, as the results from biotic and abiotic column experiments were almost analogous. Diverse retardation factors of the studied compounds emphasize the importance of considering chemical and sediment properties when assessing sorption. We also found that most of the compounds were not influenced by different flow velocities. This impact was visible neither for the modelled degradation rates nor retardation factors. Thus, not the flow velocity but the mean transit time is the most important factor influencing transport of selected pharmaceuticals.

Code of abstract: T2.7.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Physical, chemical and biological characterization as support for water governance in a hydrogeological system of Colombia.

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KEY WORDS layered aquifer, groundwater management, conceptual hydrogeological models, sustainability.

ABSTRACT
The understanding of the physical, chemical and biological system, is an indispensable precondition to address groundwater management. This understanding is based on the Conceptual Hydrogeological Models, which contain different interpretations and their validity is achieved through the application of specific research techniques (Numerical modeling, hydrochemistry, isotopy, process evaluation and biological functions). This paper describes the experience carried out by an academic team that, together with entities responsible for the protection of water resources, established strategic alliances to improve the knowledge of a hydrogeological system, providing new elements for governance. This study was carried out in the Urabá antioqueño zone, located north-west of Colombia in limits with the Atlantic Ocean. In the region, a complex aquifer system is located, characterized by a series of permeable, semi-permeable and impermeable layers which make it a layered aquifer, where the determination of their physical, chemical and biological characteristics and their management are a challenge for researchers because groundwater represents a strategic resource for supplying the population and developing economic activities. From the conceptual hydrogeological model, multiscale numerical modeling exercises were implemented that allowed characterize the local, intermediate and regional flow systems. Besides, by determining the natural background level, concentration ranges of chemical compounds from natural sources were obtained, in order to detect future changes in water quality. It was also possible the identification of stygofauna, which allowed the recognition of different types of organisms (stygobits, stygophiles and stygoxens) associated with underground ecosystems. These scientific elements serve as a support for the management instruments such as the groundwater management plan that is important for water governance, ensuring its future sustainability.

This work was possible thanks to the financing with resources coming from the "Patrimonio Autónomo Fondo Nacional de Financiamiento para la Ciencia, la Tecnología y la Innovación Francisco José de Caldas".

Code of abstract: T2.7.7
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Security of groundwater abstraction in the deep coastal Bengal Aquifer System revealed by environmental tracers

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KEY WORDS Water security, Bengal Aquifer, Environmental Tracers, Abstraction

ABSTRACT

Deep groundwater from the coastal Bengal Aquifer System (BAS) is a critical water resource for over 80 million people who live in the coastal region of India and Bangladesh. Groundwater at shallow and intermediate depths has high salinity and elevated arsenic concentrations, and deep groundwater represents an invaluable, perennial source of fresh drinking water. Deep pumping is projected to intensify to meet growing freshwater demand, however, knowledge of the vulnerability of the deep groundwater is restricted to predictions from models, with very few direct observations. Here we report new evidence from environmental tracers, which demonstrates the general resilience of deep groundwater to vertical migration of contaminants, even in areas of intensive pumping. ^{14}C-DIC results give groundwater residence times of between (10^3-10^4 years) for groundwater > 150 m and modern groundwater age tracers reveal shallow circulation and borehole scale by-pass flow at some pumped sites. This study provides the first multi-site assessment of age-depth profiles within the coastal Bengal Aquifer System and new evidence consistent with high regional anisotropy in the groundwater system offering protection to deeper groundwater.

Code of abstract: T2.7.8
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Strontium Isotopes as Natural Tracers in the Aquifer Storage and Recovery, Thailand

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KEY WORDS: strontium, isotope, artificial recharge, aquifer storage and recovery (asr), Thailand

Aquifer Storage and Recovery (ASR) was a pilot project for solving flood and drought problem in the northern part of Chao Phraya river basin, Thailand. This part of Thailand always faces flooding in rainy season and drought during dry season every year. The overexploitation of groundwater during dry season especially for agriculture leads to continuously decline of water level in this area. The ASR test site consisted of two recharge wells, eight monitoring wells in shallow aquifer (35 to 44 meters screened depth) and eight monitoring wells in deep aquifer (74 to 83 meters screened depth). In this project, the excessive surface water during rainy season was treated and stored by injection through recharge wells into the underground aquifers. This would serve to raise the water level, which can be extracted for use during the dry season. To assess the efficiency of the ASR process some tracers are required. The aim of this study is to prove the suitability of strontium isotopes to follow up the artificial recharge process. The different isotopic fingerprints can be observed in surface water, groundwater in shallow aquifer and groundwater in deep aquifer. The shallow aquifer can be classified by low Sr content and high $^{87}Sr/^{86}Sr$ ratios (0.099 - 0.117 µg/g and 0.70967 - 0.71050 respectively). The deep aquifer can be classified by high Sr content and low $^{87}Sr/^{86}Sr$ ratios (0.107 - 0.134 µg/g and 0.70923 - 0.70965 respectively).The systematic variation of $^{87}Sr/^{86}Sr$ ratios in shallow and deep aquifer during artificial recharge confirmed that strontium isotopes can be used as suitable natural tracers to evaluate the movement of recharged water and the efficiency of the ASR. However, the flow direction of the recharged water cannot be clearly interpreted because of the limited number of monitoring wells, small distance between each monitoring wells and the short duration of injection.

Code of abstract: T2.7.9
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Studying dynamics of a bank filtration site via a multi-tracer approach

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KEY WORDS - bank filtration, residence time, temperature, 222Rn, delta18O-2H

ABSTRACT

In Quebec province, an increasing number of municipalities rely on bank filtration (BF) as a relatively low-cost method to supply drinking water to the community. It consists in pumping groundwater in the vicinity of a lake or a river in order to induce a hydraulic gradient resulting in the infiltration of the surface water. Given the filtration capacity of the soils and when combined to a sufficiently long travel time, the infiltrating water can be naturally decontaminated and reach potable water standard as it passes through the banks.

Residence times of the infiltrating water into the bank and mixing rates with groundwater are the key parameters to anticipate anthropic and climatic constraints. Their assessment is therefore crucial and complex due to the transient regime occurring in the BF plants. Hence, estimating these parameters according to steady-state assumptions, as usually developed, can lead to a misleading design and a high contamination hazard.

The aim of this study is to develop a simple characterization method to better understand the spatiotemporal dynamics of BF sites. A multi-tracer approach has been developed and applied to a Lake BF site in Quebec. Monthly sampling and measurements were conducted resulting in a one-year dataset for physico-chemical parameters, geochemistry, radon isotope (222Rn) and stable isotopes of water (delta18O-2H). Results reveal that temperature provides noteworthy data regarding the influence of pumping patterns on the composition of the pumped water. Radon time-series give insights on the dynamics of residence times of the surface water into the bank. The high seasonal variability of the infiltrating surface water component is revealed by stable isotopes of water.

Code of abstract: T2.7.10
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

The assessement of urban groundwater hydrochemistry in Seoul, South Korea, using combined pattern recognition methods

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KEY WORDS urban groundwater management, hydrochemistry, spatial control, self-organizing map (SOM), fuzzy c-means (FCM) clustering

ABSTRACT

In order to establish a strategy for proper urban groundwater management, comprehensive understanding of its hydrochemistry is needed. This study aims to overall evaluate the complex hydrochemistry of groundwater in Seoul, South Korea. A total of 343 groundwater samples could be grouped into 91 neurons by the self-organizing map (SOM) technique, and these neurons were further classified into three representative water types by fuzzy c-means (FCM) clustering. Group 1 represents non- or less-polluted groundwater (on average, TDS = 194.5 mg/L and NO_3 = 6.9 mg/L) whose chemistry is mainly determined by water-rock interaction. Group 1 groundwater is preferentially located beneath forest areas surrounding the city center. Group 2 represents highly polluted groundwater which is characterized by high concentrations of TDS and nitrate (326.2 mg/L and 42.6 mg/L on average, respectively). Group 2 groundwater occurs ubiquitously in the center of Seoul and is mainly affected by the influences from sewage water leakage from broken sewer pipe networks. Group 3 groundwater also represents the highly contaminated groundwater (average TDS = 527.1 mg/L). However, its average nitrate concentration (13.1 mg/L) is far lower than that of Group 2, likely due to the occurrence of denitrification. In the city center area, excessive groundwater pumping may induce the local accumulation of organic contaminants (e.g., sewage wastewater), consequently resulting in the generation of reducing conditions being sufficient for denitrification. The results of this study showed a regional spatial control of groundwater quality by land use and can be used to set up proper measures of groundwater resources management in Seoul and other metropolitan cities.

Code of abstract: T2.7.11
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Protecting the Karst Te Waikoropupu Springs in New Zealand

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KEY WORDS water clarity, nitrate, dairy farming, environmental protection, conservation order

ABSTRACT
Te Waikoropupu Springs are New Zealand's largest, have some of the clearest freshwater worldwide, are of great spiritual value to local indigenous Iwi (tribes), and are a major tourist attraction. They emerge from two interconnected karst aquifers in Arthur Marble with mean residence times of 10.2 and 1.2 years, respectively. The very high water clarity is due to action of endemic groundwater biofilms and stygofauna. This karst system has very high conservation values.
To protect these, the aquifers should be managed to ensure that NO_3-N does not exceed 0.4 mg/l. The unconfined aquifer is 135 km^2 with farming on 45 km^2 of lowland, free-draining gravels that receive about 2.5 m/year rainfall. As dairy farming has intensified with more fertilizer and irrigation, NO_3-N has risen in the Springs at 1.7% annually. There is pressure for further intensification. Intensive weekly sampling undertaken in 2016, found a median NO_3-N of 0.4 mg/l with a seasonal fluctuation related to earlier rainfall patterns. Nitrate in the hydrologically connected Takaka river also varied seasonally and was highest in wet winter months.
To control farm impacts on water quality, farmers have volunteered to stop cattle having direct access to waterways, to manage their dairy-shed waste better and to plant narrow riparian strips. There is some evidence this has helped.
The local Council process is to use stakeholders and professionals to recommend water allocation and quality guidelines. These would be included in their regional plan.
A Water Conservation Order (WCO) for the outstanding values of the aquifers and Springs complex, is also under application. This is allowed for in New Zealand law and, when granted, must be implemented by the Council. It provides stronger long-term protection, similar to National Parks, and is less susceptible to capture by vested interests.
To protect this karst system, a WCO, which offers the greatest control, is strongly recommended.

Code of abstract: T2.7.12
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Water Quality Evaluation of Choosan Spring in Nari Basin of Ulleung Island, Korea

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KEY WORDS Choosan spring, water-rock interaction, water type, factor analysis

ABSTRACT
Water quality of Choonsan spring located in Nari basin of Ulleung Island and development characteristics of aquifer around the Nari caldera basin were evaluated. Water quality of the Choosan spring and surface waters in the valley of the study area is dominated by porous pyroclastic rocks with a large surface area in Nari basin. Water type of the Choosan spring is characterized by Na-HCO_3 and surface waters in the valley is placed at the boundary from Na-HCO_3 to Na-Cl. Components with high determinative coefficients with respect to EC are HCO_3, Na, F, Ca, Mg, Cl, SiO_2, and SO_4. There is a possibility that high concentrations in Na and Cl are attributed to a lithological properties of alkaline series volcanic rocks which are predominantly distributed throughout Ulleung Island and an age-old volcanic activity. Eh and pH, assumed as important indicators in water-rock interaction, have nothing to do with any other components. According to the results obtained from factor analysis, cumulative percent of variance of factor 1 is 54 % while it is 25.8 %, respectively. Components with high loading to factor 1 are F, Na, EC, Cl, HCO_3, SO_4, SiO_2, Ca, NO_3, and Mg. Components with high loading to factor 2 are Mg, Ca, along with K, NO_3, DO as negative loading. It is suggested that high concentrations in Na, Cl, F, and SO_4 might be intimately related to fine-grained, alkaline pyroclastic rocks with high permeability and porosity favorable for the water-rock interaction. However, a wide range of investigation such as geophysical prospecting and geochemical analysis including isotope, trace element, and tracer is further necessary to better understand the characteristics of groundwater chemistry, aquifer distribution, and the water cycle mechanism of Ulleung Island.

Code of abstract: T2.7.13
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

TIDAL FLUCTUATIONS IN SALT FLATS AND ITS IMPORTANCE FOR THE CONTINGENCY PLANS

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KEY WORDS Salt flat, groundwater, cyclicity, gravitational forces, contingency plan

ABSTRACT

Tides are the cyclic change of sea level produced mainly by the force of gravitational attraction exerted by the Sun and the Moon on Earth. In general, the tides of the lithosphere or groundwater have very small wavelengths with respect to those occurring in the sea or ocean, which can vary its level by several meters, and also in the atmosphere, which can vary its height by several kilometers. However, due to the proximity of the groundwater to the topographic surface and to the large dimensions of the body of groundwater, an analogous phenomenon has been identified in the Salar de Atacama (NE of Chile). A statistical analysis of hydraulic heads data in different piezometers has been carried out with the objective of studying the high frequency oscillation of hydraulic heads in the different areas of the salt flat and the effect that the tides produce in the piezometric surface. If the time evolution of the hydraulic heads in any of the piezometers is analysed, the presence of two complete daily cycles can be quickly observed, which cannot be explained by an evaporation process, since in that case there only would be one daily cycle. The detailed study of this process can be of great importance in the establishment of the thresholds of the defined contingency plan for the preservation of the fragile ecosystems existing in the marginal zone of the Salar de Atacama, which constitute a world reference environment for the nesting of flamingos.

Code of abstract: T2.7.14
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Understanding Mg isotope systematics of variably saline groundwater in Southern Africa

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KEY WORDS: Novel isotopes, magnesium isotopes, strontium isotopes, South Africa, saline groundwater.

ABSTRACT

Stable isotopes of oxygen, hydrogen and carbon have long been shown to be excellent tracers of water movement through the meteorological cycle. However, with the almost exponential increase in analytical capabilities in recent years, much focus has been on more novel isotope systems to provide additional insights into hydrological processes. Magnesium isotopes are one such system that has been underutilised in hydrological studies. The principle reasons for this are the technically challenging nature of magnesium isotope analysis and the relatively small fractionation range observed in nature. However, as magnesium is a major component in both water and rock, magnesium isotopes are a potentially very useful tracer. Magnesium isotopes, which have been shown to be fractionated by weathering processes, have the potential to serve as powerful tracers of chemical weathering and ultimately provide insight into global climate variations. In addition, magnesium isotopes have recently been identified as a possible tracer of hominid evolution and could provide evidence for reconstructing food webs among extinct animals, and an opportunity to understand ecological interactions in deep time. Prior to the application of magnesium isotopes to various studies, the baseline magnesium isotope variation in hydrological systems needs to be established. The aim of this study is to develop an effective method of analysing magnesium isotopes in water samples and identify trends and variations that may exist in various groundwater sources from selected southern African west coast catchments where saline groundwater is an impediment to economic development. Magnesium isotopes will be used in conjunction with strontium isotopes and conventional water chemistry data to obtain a better understanding of groundwater flow systems and the geochemical processes governing their hydrochemistry.

Code of abstract: T2.7.15
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Temperature effect on groundwater quality during in-situ, long-term subsruface heating and cooling in two confined aquifers in Kanto Area, Japan

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KEY WORDS: Temperature Effect, Heating, Cooling, Groundwater Quality, Heavy Metals

ABSTRACT
Increase in subsurface temperature has been recognized below several cities in the world likely due to surface warming effects such as global warming and urbanization. The temperature increase may affect groundwater quality due to the change in solubility, chemical reaction rate, adsorption-desorption reaction and so on. However, the effect of temperature increase on groundwater quality has not been sufficiently studied. The objective of this study is to investigate the temperature effect on groundwater quality during in-situ, long-term (over the past six years) subsurface heating and cooling in two confined aquifers in Kanto Area, Japan.
Results showed that increase in concentration of several groundwater components (Li, B, Si, DOC: dissolved organic carbon, Na^+, NH_4^+, K^+, and As) was observed with increase in the subsurface temperature. Exceptionally, two groundwater components (Mg^{2+} and Ca^{2+}) decreased with increasing the temperature. All these components returned to the original concentration level with decrease in the subsurface temperature.
Relationships between variations in the temperature and groundwater chemical concentration were analyzed. Almost linear relationship was obtained for several components (Li, B, Si, DOC, Na^+, NH_4^+, K^+, As, Mg^{2+} and Ca^{2+}). The mechanisms controlling the concentration increase of groundwater components with the temperature increase are under the investigation.

Code of abstract: T2.7.16
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Assessment of radioactive nuclide and heavy metals in the groundwater around a uranium mining areas of southern China

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- KEYWORDS uranium mining areas, groundwater, radionuclides, heavy metals

- ABSTRACT
- To assess the pollution characteristics of the radionuclides and heavy metals, 17 samples of groundwater were collected in a wet, normal and dry season around a uranium mining areas of southern China, respectively. The radionuclides and heavy metals that is natural and artificial in the groundwater were measured by gamma spectrometry, graphite furnace atomic absorption spectrophotometry and microwave dissolution atomic fluorescence spectrometry, respectively. The results showed that no ^{230}Th was checked out in the groundwater of study area, but the estimated average concentration of ^{238}U,^{226}Ra,^{210}Pb,^{210}Po were 1.42μg·L^{-1},29.6 mBq·L^{-1},15.6 mBq·L^{-1},13.1 mBq·L^{-1}, respectively. The total internal dose caused by radioactive nuclides was 2.6×10^{-5}Sv, which is lower than the reference level from WHO, then it will not pose a significant hazard to people. The heavy metal concentrations of Mn, Fe, Pb and As were measured and the concentration order of groundwater was Fe＞Mn＞Pb＞As. The calculation of these heavy metal hazard indices also indicated that the heavy metal content of the groundwater surrounding the mining areas was within acceptable limits. In addition, the Pearson linear coefficient between the concentration of radionuclides and the concentration of heavy metals in groundwater were determined. Therefore, the groundwater around the uranium mining areas were safe for human health.

Code of abstract: T2.7.17
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Evaluation of the threshold value of nitrate in shallow groundwater from agro-livestock farming areas of South Korea

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KEY WORDS shallow groundwater, nitrate, background and threshold values, cumulative distribution function, Gaussian mixture model

ABSTRACT
Recently in rural areas of South Korea, the quality of shallow groundwater for drinking and domestic use is severely threatened by increased nitrate (NO_3^-) concentrations. This problem is resulted from diverse contaminant sources such as livestock manures and chemical fertilizers. For the establishment of a proper groundwater management scheme, the accurate threshold value of nitrate is required to distinguish between anthropogenic contamination and natural background. For this purpose, we interpreted the nitrate nitrogen (NO_3^--N) concentration data of shallow groundwater (n = 118,233) collected from 120 agro-livestock farming areas over South Korea. The results showed that 30.3% of total samples exceeded the Korean drinking water standard (10 mg/L NO_3—N). Statistical interpretation of data using the cumulative distribution function (CDF) and Gaussian mixture model (GMM) yielded the threshold values of nitrate: 1.3, 7.6, and 15.8 mg/L from the interpretation of CDF, while 4.7, 7.3, and 11.4 mg/L from the interpretation of GMM. Then, the estimated nitrogen loading data for two groups of samples (i.e., natural versus contaminated) were tested by the Kolmogorov-Smirnov test to select the most appropriate threshold value. The threshold value of 4.7 mg/L NO_3^--N was finally suggested as the threshold value of nitrate to differentiate groundwater bodies with significant contamination from agro-livestock farming from background groundwater bodies.

Code of abstract: T2.7.18
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Hydrogeochemical evolution characteristic in Gonghe West Basin, Northern China

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KEY WORDS: hydrogeochemical characteristic; Gonghe West Basin; ionic ratio; ion-exchange; mineral dissolve

ABSTRACT

Considering the problems of the lower research degree, higher difficult in study and great variation in hydrogeological condition of nearly three decades, we have carried on the hydrogeological survey and collected 247 water samples from phreatic aquifer and semi-confined aquifer. It is the first time to carry out the systematical analysis on the hydrochemical type, spatial distribution and evolutional mechanism. Results show groundwater flows from Ca-HCO_3 water, Ca-Mg-HCO_3 water and Ca-Mg-HCO_3-SO_4 water with the mineralization of less than 500mg/L in the piedmont proluvial-alluvial fan sloping plain on the basin edge, to the alluvial-pluvial plain in the center of basin along with the groundwater. Following the exchange of cations and due to the strong effects of evaporation and concentration, Na-Ca-HCO_3 water appears between the piedmont proluvial-alluvial fan sloping plan and the river valley proluvial-alluvial plain. Within the main groundwater discharge area of the basin ---Shazhuyu River terminal valley plain and Qiabuqia River downstream valley plain, Na-Mg-Ca-HCO_3-Cl water and Na-Cl-HCO_3 water with the mineralization of over 3000mg/L play a dominant role. Based on Na/Cl ratio diagram and Langelier–Ludwig diagram, we can learn that the aquifers in different geomorphological units of Gonghe West Basin have their unique hydrogeochemical processes. The peripheral groundwater is noticeably affected the mixing of surface water. The groundwater in Wahong River alluvial-proluvial fan on the southern edge of Gonghe West Basin has the best quality across the region. Given strong evaporation and concentration and cationic exchanges, the groundwater in Shazhuyu River Valley Plain and Qiabuqia River Valley Plain is of lower quality. The groundwater in Qiabuqia River Valley Plain is of the lowest quality because the hydrochemical features of phreatic water are affected by the mixture of high-arsenic and high-mineralization water moving up the deep fractures.

Code of abstract: T2.7.19
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Natural background level in a Colombian aquifer system as a tool for a groundwater resources management.

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KEY WORDS multilayer aquifer, groundwater management, quality, sustainability.

ABSTRACT
In many instances when we talk about environment management, it refers to the need of defining a baseline that allows to take precautions and establish necessary measures for its management starting in time, from an initial knowledge of the system functioning. In terms of the chemistry and groundwater quality, which are fundamental to guarantee that the water can be used for a particular use such as water supply, exist a lack of mechanisms and specific policies to manage it in the Colombian aquifers, so the knowledge of the baseline or natural chemical background of the hydrogeological systems is turn in a fundamental tool to the extent that this can serve as reference to evaluate quantitatively if exists or not anthropic contamination. This work was developed in the multilayer aquifer of Urabá gulf – located in the north-west of Colombia in limits with the Atlantic Ocean. Here were evaluated the main factors that can modify the range of concentrations, were identified the sources and processes that originate and affect natural chemical background and were identified their concentration ranges with the purpose of establish reference values to differentiate between natural quality and modified quality caused by human activities. With those natural concentrations ranges, the environment authority can evaluate quantitatively the existence or not of groundwater contamination based on geochemical criteria and also can detect in time possible changes in the resource quality that can appear in the future and the sources and processes that originate them. This allows to take the necessary management measures and have arguments for decision making and the promulgation of regulations that, due to the dependence of this resource and the development of human activities, more and more pressures are generated to the aquifer system that could be translated into pollution, in some cases impossible to reverse.

This work was possible thanks to the financing with resources coming from the "Patrimonio Autónomo Fondo Nacional de Financiamiento para la Ciencia, la Tecnología y la Innovación Francisco José de Caldas".

Code of abstract: T2.7.20
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Qualitative and quantitative assessment of groundwater Resources for a sustainable management in the buffer area of Limpopo National Park

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KEY WORD: Limpopo, groundwater, quantitative and qualitative data, geochemistry of trace elements,

ABSTRACT

This study is part of the research project SECOSUD II, "Conservation and equitable use of biological diversity in the SADC region: from geographic information system (GIS) to Spatial Systemic Decision Support System", granted by Italian Cooperation and Development Agency. Groundwater plays a key role in supplying water for people, living in most part of Southern Africa. Many rural villages rely entirely on groundwater abstraction for farming, irrigation, and drinking water supply, domestic uses, but groundwater supplies are increasingly threatened by contamination by various sources, and their overexploitation makes it, sometimes, to be not enough available, as for human demand for biological diversity conservation. Moreover climate change is a growing up pressure on groundwater resources availability and water quality protection.
Due to the complexity of geological and hydrogeological framework within the countries of SADC region, as Mozambique too, groundwater quality varies considerably depending on different climatic regions and on aquifer geology and thickness. Limited to the buffer zone of National Limpopo Park, in Mozambique, in the framework of the cited research project, whose aim is the protection of biodiversity and human water demand availability, in the last year it has been started a program of quantitative and qualitative characterization of groundwater, exploited inside this area. As a matter of fact, they have been collected meteorological data, referred to the last twenty years, collected in three gauging stations, rising up inside and just nearby the area under study. At the mean time it has been planned, and now they are going to be set up, twelve new gauge stations, inside the National Limpopo Park, which are going to become the meteorological network of the National Limpopo Park. Starting from available meteorological data, nowadays, it will be carried out a water budget of the National Limpopo Park area, which will be verified, in the next years, by data coming from the meteorological network, we are going to set up in the next months. On the other hand, they will be presented first results of geochemical characterization of groundwater samples collected in two different monitoring campaigns, driven, the first in October 2016, at the end of the dry season, and second in March 2017, at the end of the wet season.

Code of abstract: T2.7.21
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Multidisplinary approch to evaluate nitrogen behaviour in the alluvial aquifer of Varaždin area - Croatia

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KEY WORDS: alluvial aquifer, nitrogen, microorganisms, chemistry, Varažinska County

ABSTRACT
Nitrate is a compound of nitrogen that occurs naturally in moderate concentrations in many aquatic environments. Higher concentrations of nitrate in groundwater are typically caused by anthropogenic activities including nitrogen compounds from synthetic fertilizers and manure used in agriculture, septic systems and other waste waters. All over the world, high concentrations of nitrate are observed and can cause deterioration of groundwater and surface freshwater quality and that poses a serious problem for drinking water supplies and contributes to the process of eutrophication. An example of area with high nitrogen content in groundwater is the surrounding area of the town of Varaždin. This area is densely populated with industrial and extensive agricultural production. High concentrations of nitrate caused the shutting down of the pumping site ''Varaždin''. The research area comprises the catchment area of the pumping sites ''Varaždin'' and ''Vinokoščak''. The aquifer of the research area is composed of gravel and sand with variable portions of silt as the result of accumulation processes of the Drava River. The covering layer of the aquifer is not continuously developed. Such conditions are favourable if they are considered from the aspect of aquifer recharge, but at the same time tiny covering layer composed of clay, silt and sand particles mixed with various content of organic matter, make the aquifer quite vulnerable. The previous research that has been conducted in the proposed study area dealing with nitrates was from hydrogeological or agricultural points of view. The systematic interdisciplinary research on fate and distribution of nitrate in the aquifer has never conducted before. The paper will present first results which are obtained during first sampling campanies.

Code of abstract: T2.7.22
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.7. Groundwater quality and natural environmental tracers

Investigations on the fate of sulfonamides and tetrazyclines in the unsaturated zone - Template for authors submitting abstracts

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KEY WORDS - veterinary pharmaceuticals, degradation, transport, unsaturated zone, soil column -

ABSTRACT

Due to the eminently improvement of analytical methods in the last decade, there has been a special focus on human and veterinary pharmaceuticals contaminating the environment. In the course of different studies negative impact on humans, animals and the environment like the increasing occurrence of multiresistant pathogens caused by antibiotically active substances have been identified.

Because of the fact that no European law had been passed until 1998 regulating environmental assessment in the accreditation process of pharmaceutic substances, there is a lack of information concerning the degradation of veterinary pharmaceuticals (VP) in the environment, especially in the unsaturated zone. Thus, the main aim of this study was to better understand the behaviour of veterinary pharmaceuticals regarding microbial degradation and sorption in soils and potential leaching into groundwater. Thereby key parameters, influencing these processes, were identified, and the ecological relevance of the investigated substances was elevated.

For this reason, it has been worked with three unsaturated, undisturbed soil columns in the laboratory to receive degradation constants and sorption coefficients of two representative sulfonamides and tetrazyclines (sulfamethazine, sulfathiazole, tetracycline and chlortetracycline) in dependence of temperature and pH-value. Therefore, three kinds of soils with different characteristics in grain size, organic content and pH-value were selected (cambisol, podzol and plaggic anthrosol).
Soil columns measure one metre in depth and ten centimetres in diameter. As analytical method, veterinary pharmaceuticals were enriched by means of a solid phase liquid extraction, and identified and quantified with HPLC-MS/MS.

Code of abstract: T2.8.1
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Impacts of Unconventional Gas Exploration on Groundwater

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KEY WORDS – Gas, Exploration, Groundwater, Resources Impacts

ABSTRACT

Unconventional gas exploration and extraction (UGEE) involves hydraulic fracturing (fracking) of low permeability rock to permit the extraction of natural gas on a commercial scale from unconventional sources such as shale gas deposits, coal seams and tight sandstone.
In Europe, shale gas is currently in its exploratory phase with low numbers of exploratory wells drilled. In overall terms, shale gas projects follow the following phases. Exploratory phase which includes preliminary site identification and selection; site characterisation of the proposed site and establishment of baseline conditions for air, water, land, geology and deep-ground conditions. An appraisal phase. which includes pilot well drilling; drilling initial horizontal wells to determine reservoir properties and required well completion techniques; further development of the geological conceptual model following test fractures; wellhead and well design and construction (drilling, casing, cementing, integrity testing); multi-stage hydraulic fracturing (injection of fracture fluid and management of flowback and produced water and emissions); and well completion. The production. phase follows where the well pad is expanded and the necessary facilities constructed, including storage tanks, impoundments and secondary containment structures and the commercial production of shale gas takes place. Finally cessation of activities takes place once economical extraction of gas from the well is no longer viable and the well is decommissioned. All of these phases have the potential to impact on groundwater resources and increases competition for the resource. Focusing on two case studies on the island of Ireland we report on the potential environmental impacts of UGEE projects and operations on groundwater and surface water bodies, including the potential migration of methane, chemicals and other contaminants, from both surface and subsurface sources in two catchments. The findings are informed by an objective assessment of the risks and hazards posed by UGEE projects and operations and supported by a literature review and experience from other jurisdictions. Mitigation measures to address groundwater water impacts are critically reviewed and presented.

Code of abstract: T2.8.2
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Integrating Hydrus and Modflow to predict on-site wastewater trestment contaminant transport in different aquifers

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KEY WORDS Groundwater modelling, on-site wastewater treatment, Vadose zone modelling, cluster developments, density

ABSTRACT

Groundwater is an important resource in the Republic of Ireland both from a water supply perspective as well as an environmental perspective as the baseflows in Irish rivers during dry weather periods are generally supported from groundwater sources. Approximately one third of the Irish population is served by decentralised wastewater treatment systems, many of which have been built to older standards and it is not known what the combined effects of groups of treatment systems in a relatively dense arrangement may have on groundwater quality, particularly in areas of varying hydro(geo)logical settings. The impact on groundwater quality from high density clusters of unsewered housing across a range of hydrogeological settings has been modelled using an integrated approach with HYDRUS and Modflow. Five separate cluster development sites were selected, each representative of different aquifer vulnerability categories across Ireland. Utilising the results of previous research projects which monitored the breakdown of contaminants through the vadose zone at various depths and across various subsoil categories, unsaturated zone models for contaminant transport were developed which represented field conditions at four of the study sites. A fifth study site which was situated within a karst landscape had secondary treated effluent from a cluster development discharged directly to groundwater (bedrock) via a sinkhole (dloine). The output from the HYDRUS 2D models and wastewater sampling at the karst site provided the resulting hydraulic and contaminant fluxes at the water table and this was then used as inputs into MODFLOW MT3D models to simulate the groundwater flows. The groundwater MODFLOW (MT3D) models were calibrated against field data which was collected from a series of monitoring boreholes during the study. The results of the study indicated that existing densities at each of the sites only showed limited and localised impacts on groundwater quality. The study also simulated the effects of increasing cluster densities at each site and these simulations also indicated little impact at any of the study locations up to a density of 6 units/hectare with the exception of the *Extreme* vulnerability site.

Code of abstract: T2.8.3
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Regulating water extraction and salinity in an alluvial groundwater system in a heavily modified, coal-bearing, coastal catchment with sparse data.

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KEY WORDS salinity, water extraction, mining, regulation

ABSTRACT
The Hunter River catchment, in coastal New South Wales, eastern Australia, is of major economic, social and environmental importance. It is underlain by major Permian coal deposits of the Sydney Basin which are mined extensively throughout the catchment. Discharge of saline water from coal mines into the Hunter River is currently controlled by the Hunter River Salinity Trading Scheme (HRSTS) which sets a salinity target for electrical conductivity (EC) of the river when discharge is permitted of EC≤900 µS/cm. The Goulburn River is the major upstream alluvial tributary of the upper Hunter River but is not part of the HRTS, despite mining in its catchment. Salinity in the Goulburn is derived mainly from groundwater associated with the coal measures, and often reaches median electrical conductivity (EC) levels greater than 800–1000 µS/cm. Ground and surface water extraction, mine discharge and frequent droughts influence river salinity. The impact of climate change is an additional concern. We use the sparse available data to investigate the interaction of surface and groundwater with land use change, climate and management and their effects on discharge and salinity in the Goulburn and a key freshwater southern tributary, Widden Brook. Findings are evaluated with respect to the target salinity of the HRSTS, as well as cease-to-pump provisions in Water Sharing Plans. It is shown that the minimum flow in the Goulburn to maintain EC at or below the HRSTS target is 91 ML/day, close to the 0.75 percentile of flow.

Code of abstract: T2.8.4
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Preservation of Groundwater Production Potential in Israel

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KEY WORDS: Groundwater production, well structure, lifetime, corrosion, incrustation

ABSTRACT
Average groundwater production in Israel is ~1,000 million cubic meters (MCM) per year for all uses (domestic, irrigation and industry). Groundwater exploitation is taking place today by ~1,500 active production wells. Most of the current production is by old wells that were drilled more than 50 years ago, in the 1950s and 1960s.
Over the past few decades there has been a steady decline in the production capacity of groundwater because of the shutdown of many wells for various reasons including: hydrogeological conditions (water level depletion, groundwater pollution), operational and economic considerations, regulation, and specific protective zone guidelines. Technical failure of the well structure is a dominant factor affecting the lifetime of a well and is in many cases the initial trigger for some of the other causes mentioned above.
The current project included an in-depth analysis of all pumping wells in Israel, with a detailed examination of a selected group of 200 representative wells. The main factors and characteristics involved in the corrosion and incrustation processes of boreholes are defined and described in detail.
Based on the above, a methodology was developed for estimating the lifetime of a well according to hydrogeological and technical characteristics. Based on the results, the average lifetime of a well is around 60 years. Accordingly, the loss of production capacity in future years due to well failure was estimated to be ~500 MCM by 2030 and an additional 300 MCM by 2050. A well drilling and rehabilitation plan to maintain current production potential is presented, along with initial cost estimation. Finally the current drilling capacities and capabilities of existing drilling contractors in Israel are reviewed, and the main gaps for executing the preservation plan evaluated.
The main conclusion from the study is that a fundamental change in state policy regarding the drilling of new wells and renewal of old wells is essential in order to maintain the production potential of groundwater, which is still a main source of water in the national water supply system. Execution of the necessary drilling plan requires an exceptional lineup of personnel and effort as well as substantial budgets, and it will be directed by the Israel Water Authority.

Code of abstract: T2.8.5
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Subsidence management in Oslo - from GIS analysis to urban planning

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KEY WORDS Ground water management, urban planning, 3D modelling, subsidence, subsurface information analysis

ABSTRACT

Oslo is the capital of Norway; a small town by global standards, but still a rapidly growing city. The population of Oslo is one of the fastest growing in Europe, a tendency giving both challenges and opportunities. The city will require large investments in communication systems and new dwellings. Underground space is already widely used for transportation, storage, extraction of heat and for foundations of buildings and infrastructure, due to the rapid growth of the city the underground use is expected to develop rapidly. The city of Oslo deals with geological challenges such as subsidence due to deep horizons of clay, quick clays *and* alum shale's that contains enhanced levels of radium and uranium. Future development in the subsurface can increase the subsidence if the right measures are not made. We know today that subsidence and lowering of groundwater levels affects constructions that are not founded in bedrock, and causes damages on buildings and infrastructure.

Between 2013-2016 the Oslo Sub -Surface project was carried out. Five municipal agencies participated in the project; Agency for Planning and Building Services, Agency for Water and Sewerage Works, Agency for Urban Environment, Agency for Real Estate and Urban Renewal and the Cultural Heritage Management Office. The participation in COST TU1206 – Sub urban network has been an invaluable source of I knowledge and ideas to us and has had an important impact on the result of the project. The results from the project will be available in the final report along with an action plan

Subsurface information as a tool for subsurface management.

An efficient and fact based management of the subsurface is dependent on the availability and quality of sub-surface information. Good quality information is generated from sufficient and accurate data. But it is not enough to collect data, relevant information also needs to be available to the public when needed.

Our conclusion is that the most efficient way to distribute sub-surface information is a joint municipal system. To be able to organise such a system a subsurface information need analysis was carried out during the project.

We also propose a groundwater database that manages and distributes all groundwater data in the city. It should be obligatory to report any groundwater measurements in the city to the database. We also recommend the city to establish a groundwater measure program.

To facilitate the availability of sub-surface data the Oslo we developed methods to map subsurface information. The following examples are relevant to groundwater management:

- a building foundation map that allows us to easily identify buildings that are sensitive to groundwater changes and subsidence.
- digitized and visualised geotechnical information from the municipals geotechnical archive. We digitized geotechnical boreholes and built a 3D model of the quaternary layer in two test areas in central Oslo. The model gave us an important experience about how information is understood depending on how it is visualized and communicated. The model was received with impressed nods and interest, but little comprehension of what it was actually trying to communicate – the distribution and depth of clay and quick clays. We later simplified the model to a 2D map showing the areas where we had information about quick clays thickness. The map was immediately taken into use and is presently being considered in at least one area zoning plan.
- subsidence attention map; it is based on a GIS-analysis using three layers and maps
  - depth to bedrock – based on approximately 200 000 geotechnical drillings from 1912 - 2015
  - quaternary geology – national maps provided by the Norwegian Geological Survey
  - average deformation based on In SAR data from 2008-2015

Subsurface information and planning

By using the full potential of the Norwegian planning and building act future use of the subsurface in Oslo will be more efficient. We mean that this will reduce conflicts between individual projects as their boundaries are set at an early planning stage. If information of ground conditions is considered at an early planning level, development of sensitive areas can be avoided or adapted to the known conditions. Costs can be estimated more accurately and individual construction projects will be more successful.

To succeed we need to increase the knowledge and competence about the sub-surface in the municipality.

The municipal masterplan covers all of the city's 460 km² and is currently under revision. It includes major existing and planned sub-surface transportation infrastructure. We propose that the revised municipal masterplan also should identify the need for bufferzones. To reduce subsidence, we propose that groundwater levels should be protected in the revised version.

We propose a **municipal sub-plan for the subsurface** – much like the one developed in Helsinki. The purpose is to coordinate larger existing and future sub-surface constructions and to regulate bufferzones for each construction. New projects should be given "their" place. Ground conditions such as alum shales, quick clay and depth to bedrock should be considered for each project.

Area development plans and **detailed plans** should be used to detail buffersones and depths of large subsurface constructions already described in the municipal sub plan. For projects above ground, or partly placed in the subsurface a "sub-surface information analysis" should be carried out in order to provide relevant sub-surface information into the planning process.

For **building projects** there is a need for more information about ground conditions and sub-surface structures at this level. It would generate more accurate claims to the developer. There is a gap in national legislation; sub-surface constructions are not included in the building application process. This means that it is not possible for us to manage where for example single energy wells or heat pumps are drilled or dug down. We strongly recommend to change this.

Code of abstract: T2.8.6
Type of presentation: Oral presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Water Sensitive Design Scenario Planning for Cape Town using an Urban (Geo)Hydrology Model

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KEY WORDS Numerical modelling, water sensitive design

ABSTRACT
The natural water cycle is dramatically altered in and around Cape Town, South Africa. Reticulated water is imported from an adjacent catchment; runoff is captured and delivered to canalized storm water drains and to discharge points downstream of the urban area; infiltration is dramatically reduced by hard surfaces; and water quality is affected by a variety of sources. The City also faces water-related challenges including areas without waterborne sewage, and the water supply system requires augmentation by 2021 to meet projected demand. The Cape Flats Aquifer underlies the majority of the urban area and is considered an important resource for meeting future supply to Cape Town, yet the groundwater quality is considered one of the key hindrances.

Recognizing the impact that Cape Town has on the water cycle, Water Sensitive Design (WSD) is promoted by the City as an approach that can manage all parts of the urban water cycle in a way that mimics natural hydrological regimes, and reduces negative impacts of flooding and pollution. But, not all WSD measures will work everywhere. This paper outlines a quantitative assessment of the impacts of various WSD measures on groundwater and surface water in the greater Cape Town area, using surface and numerical groundwater model(s).

The findings indicate that over 10 million m^3/a of groundwater is available from hypothetical wellfields, without managed aquifer recharge. In response to concerns over groundwater quality, protection zones are identified for the hypothetical abstraction sites and illustrate that these are small. The aquifer can support the decentralised abstraction scenarios tested. Current policy that encourages dispersed groundwater use for non-potable purposes as a means to reduce potable water demand is supported. Policy specifying that current levels of infiltration should be maintained at new developments is supported, as the models showed that impervious areas have a significant impact on recharge. To promote this the suitability for infiltration based on current and future depth to groundwater has been mapped with areas proposed for future development.

Various policy related recommendations and recommendations for the continued use of the developed models are made, as tools for pre-feasibility testing of WSD and groundwater supply scenarios.

Code of abstract: T2.8.7
Type of presentation: Poster presentation
Topic: T2. Sustainable Management of Groundwater Resources
Session: T2.8. Management of groundwater systems in urban and mining areas

Urban hydrogeomorphology in fractured hardrock systems: Porto urban area (NW Portugal)

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KEY WORDS Hydrogeomorphology; Groundwater; Infiltration potential index; Urban areas; NW Portugal

ABSTRACT

Hydrogeomorphology is focused on the relationship between hydrologic processes and the interaction of geomorphic processes relating surface water/groundwater flow regime, linking together physical geography, geology, hydrogeology, geomorphology, remote sensing, applied geophysics, soil and rock geotechnics, climatology and natural hazards. Hydrogeomorphology allows a better understanding of the storage and circulation of groundwater, as well as the rational use of available/renewable quantities. Hydrogeomorphology is an excellent tool to calculate the infiltration rates, and may also lead to measures to protect these sensitive areas. One of the most important applications of hydrogeomorphology is the definition of areas with the greatest potential for circulation of groundwater and where the potential for infiltration will be greater. These features are represented by suitable mapping, based on multicriteria analysis, carried out in a GIS environment. The factors influencing the infiltration potential are, namely, lithology, structure, weathering grade, tectonic lineaments density, land use, drainage density, slope, rainfall, sewer network density, stormwater network density and water supply network. These factors can be overlapped and cross-linked in a GIS environment, according to different weighting factors and different specific weights within each factor. The constructed base maps are used to calculate the areas with the highest infiltration potential, applying the spatial analysis functions of the GIS software.
In this work, a methodological GIS-based mapping approach for the assessment of groundwater systems in the urban area of Porto city (NW Portugal) is presented. The procedure was based on techniques related to remote sensing and hydrogeomorphological mapping, along with a hydrogeological inventory fieldwork and groundwater well features. Hydrogeomorphological mapping and several resultant thematic maps were created to outline the potential groundwater infiltration areas. This approach contributes significantly to the development of the hardrock hydrogeological conceptual site model, and may provide effective guidelines for decision-making in the groundwater and surface water protection, planning and management.

Code of abstract: T3.1.1
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Arsenic contamination of the Quaternary aquifers of the Red River delta, Vietnam controlled by the hydrogeological processes

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KEY WORDS alluvial aquifers, arsenic, flow modeling, groundwater, Red River delta

ABSTRACT
Transport of arsenic in aquifers under minor human influence was investigated in the uppermost part of the Red River delta, Vietnam, west of a depression cone formed by groundwater pumping in Hanoi. A flow model for the current situation in the Quaternary aquifers was set up in FEFLOW based on remote sensing, geophysical and (hydro)geological data gathered during field work conducted in 2014-2017. Sedimentological development and simulated flow patterns were compared with changes in groundwater chemistry.
Groundwater in the Red River delta flows in two systems; a local flow system with young groundwater (<40 years) circulating recharge through the shallow parts of the aquifer system to surface water bodies and a deeper, regional flow system with flow paths discharging at the Red River or flowing parallel to the river toward the sea. The local flow system is seasonally recharged with the surface water, which is confirmed by enrichment of groundwater in ^{18}O at the wells located in the vicinity of water channels. Intensive erosional processes in the fluvial environment and a low subsidence rate have led to hydraulic connections between Pleistocene and Holocene aquifers and created preferential flow paths. The regional flow system in the Pleistocene aquifer is partially recharged with groundwater seeping from the Holocene aquifers.
It is common that arsenic concentration in groundwater decreases with an increasing sediment age. Natural hydrogeological processes in the upper part of the Red River delta modify this pattern. The lowest arsenic levels (<1 µM/L) are found in the Pleistocene aquifer close to the recharge zone in the mountains bordering the Red River delta and in the Holocene aquifers, where most of the fine grained sediments has been washed out. Groundwater with the highest arsenic concentration (>5 µM/L) is hosted in the most recent Holocene sediments and in the Pleistocene deposits recharged partially by arsenic-contaminated groundwater from Holocene aquifers. Intrusion of groundwater with high arsenic levels into previously uncontaminated Pleistocene aquifers is induced not only by an intensive groundwater pumping in the area of Hanoi, but also takes place through Holocene-Pleistocene connections via naturally occurring hydrogeological processes in the areas located outside of the depression cone.

Code of abstract: T3.1.2
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

The effect of a fully-integrated model parametrization on groundwater-surface interactions in boreal esker-mire landscape: example of the Olvassuo aapa mire in Finland

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KEY WORDS global sensitivity analysis, fully-integrated modelling

ABSTRACT
Fully-integrated physically-based groundwater-surface water models are valued tools to study groundwater-surface water (GW-SW) interactions. Despite this fact, little applications exists of integrated physically-based modelling investigating the GW-SW interactions at large scales. Long computational times and high data requirements are generally considered to be limiting factors of use this type of models. However, better understanding of GW-SW dynamics and the impact of anthropogenic activities may be an interest in many areas that do not provide enough data for integrated model building and calibration.
One of such systems are boreal aapa mire-esker systems. Aapa mires, also known as patterned fens are large-scale minerotrophic fen complexes that in Finland are commonly hydraulically connected to unconfined glaciofluvial esker aquifers. Whereas esker aquifers may be well characterized due to their use as drinking water sources, little information exists about hydrological behavior of aapa mires due to their remoteness and heterogeneity hampering modelling of such landscapes.
To deal with problem of model parametrization we built a steady-state model of an aapa mire-esker system located in Northern Finland using integrated physically-based code HydroGeoSphere and applied an elementary element approach, also known in literature as Morris method – a qualitative global sensitivity technique that is particularly suitable for screening large models. Our main objective in this study was to determine possibilities to quantify reliably GW-SW interactions in aapa-mire esker systems and what kind of measurement data will help to calibrate such models.
The results indicate that the properties of surrounding mire (or peatland) landscape can have significant effects on the overall groundwater levels in the unconfined aquifer and fluxes between the esker and mire/peatland areas. Due to unrealistic shapes of pressure-saturation-hydraulic conductivity relations caused by random sampling of Van Genuchten parameters, the model sensitivity to these parameters can be overestimated. In conclusion, the parametrization of wetland areas should be of a particular interest when modelling esker-aapa mire systems.

Code of abstract: T3.1.3
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

A fully coupled SWAT-MODFLOW model to simulate surface-groundwater interactions: application to the Gharehsoo River Basin, Iran

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KEY WORDS SWAT-MODFLOW-NWT-Surface and groundwater Interactions- Gharehsoo River Basin

ABSTRACT

Although groundwater and surface water are essentially one resource, physically connected by the hydrologic cycle, local water laws and water policies in many countries often still consider groundwater and surface water as separate entities. A noteworthy exception to this dichotomy may be the recent European Water Framework Directive of year 2000 which attempts to abrogate this separate view by promoting a fully integrated approach of surface and groundwater in a basin. From a modeling point of view, integrated simulation of surface and groundwater, taking into account their hydraulic interactions, still represents some challenge, so that most of the time it is not yet part of routine water budget and/or management investigation. Instead, separate models for these two compartments of the hydraulic cycle are commonly used, such that the Soil and Water Assessment Tool (SWAT) for surface water and the Modular Three-Dimensional Finite-Difference Groundwater Flow (MODFLOW) model for groundwater. Although some attempts to interconnect these two models for an integrated simulation of surface- groundwater interactions, have been made in recent years, many challenges to do this properly still remain.

The present study aims to shed light on the complex interaction of surface and sub-surface hydrology of the Gharehsoo river basin in northwest of Iran by means of new SWAT-MODFLOW fully-coupled model. To that avail, the SWAT- surface water model was set up to simulate the monthly discharges for 5 outlets within the watershed during a time period of 35 years (1978 to 2012). Concurrently, a groundwater flow model was set up by MODFLOW-NWT, a standalone program intended to solve problems involving drying and rewetting nonlinearities in the unconfined groundwater-flow equation, to simulate groundwater levels and -discharge. The linkage of the two modules in the new SWAT-MODFLOW model consists of passing HRU-calculated deep percolation as recharge to the grid-cells of MODFLOW and, in return, exchange groundwater-river discharge calculated by MODFLOW's river package water with the river channels of SWAT which is the added / subtracted from the SWAT-calculated streamflow from surface runoff and soil lateral flow to streams.

As groundwater recharge and discharge and, in particular, pumping change significantly seasonally, time in the MODFLOW module was discretized to represent each season as one stress period in which there are six time steps. The SWAT-MODFLOW was calibrated and validated over the time period 1988-2012 and 1978-1988, respectively. Results show that surface and groundwater interactions are significantly changingover the time and space.

Code of abstract: T3.1.4
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Catchment controls on storage and low-flow dynamics: a hydrogeological modelling approach.

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KEY WORDS hydrogeological models, drought, integrated water resources assessment

ABSTRACT
Periods with scarce precipitation will likely occur more frequently and last longer under changing climatic conditions. Low stream flows and reduced groundwater recharge can have dramatic consequences for many sectors. It is thus crucial to develop tools to identify regions at risk and to quantify their vulnerability to droughts. This can only be done by considering both groundwater and surface water resources.
To better understand groundwater and stream dynamics under dry conditions, water storage and release processes of catchments need to be characterised. Our approach is thus to analyse the control mechanisms of physical catchment properties such as geology, hydrogeology and topography on storage processes and low-flow dynamics. Vulnerability to droughts can then be assessed based on catchment characteristics.
Disentangling the various control mechanisms of catchment physical properties on its dynamics is highly complex. We therefore use synthetic hydrogeological models to systematically quantify the impact of geology, hydrogeology and topography on catchment dynamics. The physically based numerical model HydroGeoSphere is used, which simulates surface water and groundwater in a fully coupled way. More than 400 synthetic models are designed with varying geometrical parameters such as river and hillslope, as well as bedrock and alluvial aquifer hydraulic conductivity and porosity. A clear correlation between the water dynamic storage volume and low-flow dynamics in surface water is observed: the higher the dynamic storage, the more stable the streamflow and the resilience to drought. Models results indicate that dynamic storage strongly depends on geometry and porosity - defining the total porous volume available - as well as on the dynamics governing parameters hillslopes and bedrock hydraulic conductivity. Based on these results, the geological and topographical configurations of a selection of Swiss catchments are characterised. The main geological units and sub-catchments combinations are then tested with new synthetic models. The validation of the results with these more complex models and with observations would allow assessing the water resources drought sensitivity of regions based only on catchment physical properties.

Code of abstract: T3.1.5
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Hydrodynamic and geochemical analysis of groundwater-surface water interactions (Ljubljansko polje, Slovenia)

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KEY WORDS groundwater-surface water interactions, isotope analyses, hydrological modelling

ABSTRACT
Aquatic systems are among the most sensitive of all ecosystems to anthropogenic as well as natural stressors such as pollutants (e.g. by nitrates, metals, and other toxic compounds), degradation of aquatic environments, effects of climate change that influence water quantity and quality. Thus, there is urgent need to improve our knowledge to understand of groundwater and surface water interactions. The aim of our work is to determine groundwater-surface water interactions in the Ljubljansko polje aquifer system, which is an important drinking water source for the Slovenian capital city Ljubljana and its soundings.
Groundwater-surface water interactions were described and quantified with statistical techniques and natural tracers – isotopes. The latter were used for: (1) determining sources of groundwater using $\delta^{18}O$ and $\delta^{2}H$, and (2) to estimate the mean residence time of groundwater using ^{3}H and $^{3}H/^{3}He$. In the last stage of the study the spatio-temporal variability of the groundwater flow and infiltration pathways from the two main groundwater sources was simulated: the Sava River and spatial percolation from precipitation and snowmelt. The system proves to be highly sensitive to dynamics of these surface bodies. For this reason the important upper boundary conditions of the hydrogeological model, which was built in FEFLOW, were defined with the MIKE11 and WaSiM software. The study provides a useful tool set for a better understanding of surface-groundwater flow dynamics. It can form the baseline for an integrated system for drinking water protection in central Slovenia and, when upgraded, for the projection of future water availability in response to climate change.

ACKNOWLEDGEMENTS
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Code of abstract: T3.1.6
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Relations between mineralogical compound and hydrogeological properties of typical fine grained sediments in eastern Croatia

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KEY WORDS clay mineralogy, specific surface area, particle size distribution chart, Atterberg limits,

ABSTRACT

As part of the project of determination of purification parameters of fine grained sediments covering the wellfield Cerić, mineralogical and hydrogeological/geomechanical analysis were conducted on core samples from the exploration boreholes. Geomechanical analyses (grain size analyses, Atterberg limits and natural humidity and permeability testing in oedometer) and mineralogical analysis (qualitative mineralogical analysis) were conducted on drilled samples. This research will describe the relations between mineralogical compound and geomechanical properties along with description of analytics. Identification of the hydrogeological properties was carried out based on the AC classification and grain size distribution data. In such qualitative and quantitative treatise on numerous physical characteristics of the soil, triaxial texture diagram of the statistical distribution of sand, silt and clay was used. This study presents a clear functional link between permeability and specific surface area of the sample and numerous correlations between specific surface area and Atteberg limits. The values of liquid limits for every individual sample from exploration boreholes are used to calculate the mass specific surface area. Qualitative mineralogical analysis on non-oriented (powder) samples was also performed using X-ray diffraction. These analyses were performed on a total of 5 samples. Results of mineralogical analyses showed that the tested samples predominantly contain quartz and illite with muscovite which are very often the basic mineralogical elements of clay fraction. From clay minerals, kaolinite and chlorite are also present and to a lesser extent swelling clay minerals (smectite, vermiculite). The results of mineralogical analysis, (according to specific surface area) correspond well with the results of geotechnical tests, which indicate the high quality of some known relations between specific surface area and Atterberg limits.

Code of abstract: T3.1.7
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Recovery test interpretation under non ideal conditions

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KEY WORDS - recovery test, time-dependent pumping rate, equivalent time, hydraulic properties, conceptual model

ABSTRACT
Pumping tests are usually performed during aquifer characterization to gain hydraulic information about the system and to, ultimately, estimate hydraulic properties such transmissivity and storage coefficient. Among the methods employed, the recovery test measures the water level response in surrounding observation wells after the termination of pumping. Parameter estimates obtained from the interpretation of the water head response depend on the range and quality of available drawdown and pumping rate data (data acquisition) as well as on the approach used for the interpretation (analysis techniques). In this work, we analyse the limitations of Agarwal's method for interpreting the recovery test under non-ideal conditions and we finally propose a new approach to overcome its limitations.
In this context, we first examine whether Agarwal's method is valid under non-ideal conditions: constant-head, a leaky aquifer, the presence of an impermeable barrier or a time-dependent pumping rate. Our results show that, once the Jacob's hypothesis is achieved, Agarwal's method provides adequate parameter estimates for nearly all system conditions except for a time-dependent pumping rate. In this situation, a new equivalent time should be used instead to better represent the true pumping history utilized during the pumping test.

Code of abstract: T3.1.8
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Subsoil geostatistical modeling as tool for hydrogeological modeling: Transitional Probability approach applied upon a heterogeneous site

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KEY WORDS 3D subsoil modeling, transition probability, heterogeneous site, arsenic contamination.

ABSTRACT
Nowadays, a detailed hydrogeological characterization is the base of an effective hydrogeological modeling aimed to plan and manage both the groundwater and the environment systems. Every single groundwater numerical simulation needs a hydrogeological conceptual model of the subsoil in order to define parameters and boundary conditions as well. The better the subsoil is reconstructed, the more accurate the results of the modelling will be. Several methods are available to perform a 3D simulation of the subsoil; however, their application depends on the heterogeneity of the investigated area. The stratigraphic setting can be simulated using the transition probability that models heterogeneities such as fining or coarsening-upward trend. This study aims to perform a 3D model of a heterogeneous site of 3.8 km^2 close to the Venice lagoon (NE Italy). This area is relevant from the environmental perspective because the shallower aquifer is affected by arsenic contamination. Approximately 119 stratigraphic logs are available in this site, confirming the presence of alluvial deposits (clay, silt, sand and peat) with high heterogeneity. The flood plan deposits are dominant, and the frequently avulsions of the rivers contributed to increase the heterogeneity of the system. Considering that, we decided to use a transition probability approach to perform the 3D subsoil model. Firstly, we analyzed borehole data to calculate material proportions, mean lens lengths and transition probabilities. Secondly, the transition probabilities were used to generate multiple realizations of the subsoil heterogeneity. Every realization was conditioned by borehole data, preserving the geologic tendencies. The procedure shaped a detailed 3D structure of lithological architecture, which allows for the spatial estimation of the likely arsenic source materials. This information is fundamental to perform a further reactive transport model for arsenic contamination, improving the geochemical learning on arsenic mobilization. Therefore, the 3D subsurface model assumes importance both as starting point to perform further environmental analysis and aid for local stakeholders' decision process.

Code of abstract: T3.1.9
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Nonlinear consolidation in randomly heterogeneous highly compressible aquitards

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KEY WORDS Land subsidence, stochastic modelling, Monte Carlo, heterogeneity, groundwater

ABSTRACT
Severe land subsidence due to groundwater extraction may occur in multiaquifer systems where highly compressible aquitards are present. The highly compressible nature of the aquitards leads to nonlinear consolidation where the groundwater flow parameters are stress-dependent. The case is further complicated by the heterogeneity of the hydrogeologic and geotechnical properties of the aquitards. We analyze the effect of vertical heterogeneity of hydrogeologic and geotechnical parameters on the consolidation of highly compressible aquitards. Our approach consists of one-dimensional Monte Carlo numerical simulations of the groundwater flow equation with stress-dependent parameters and where the lower boundary represents the effect of an instant drop in hydraulic head due to groundwater pumping. We generate 2000 realizations for each of the following parameters: hydraulic conductivity, compression index, void ratio and m (an empirical parameter relating hydraulic conductivity and void ratio). The correlation structure, the mean and the variance for each parameter were obtained from a literature review about field studies in the lacustrine sediments of Mexico City. Our results indicate that among the parameters considered random hydraulic conductivity has the largest effect on the ensemble average behavior of the system when compared to a nonlinear consolidation model with deterministic initial parameters. In addition, random hydraulic conductivity leads to the largest variance (and therefore largest uncertainty) of total settlement, groundwater flux and time to reach steady state conditions.

Code of abstract: T3.1.10
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Flow and transport parameters in coarse gravel unsaturated zone

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KEY WORDS: unsaturated zone, lysimeter, coarse gravel, hydraulic parameters, transport parameters, HYDRUS 1-D

ABSTRACT

The vulnerability of an aquifer to pollution is directly related to hydraulic and transport characteristics of the unsaturated zone. Understanding the mechanisms and rates of movement of pollutants in unsaturated zone is an important issue in the process of groundwater protection. Tracing experiments are very valuable tools to investigate characteristics, groundwater flow and solute transport in the unsaturated zone.

Flow and transport parameters of coarse gravel unsaturated zone have been studied with tracing experiment using a lysimeter facility in the Selniška Dobrava aquifer (N Slovenia). Dimensions of the lysimeter are 2x2 m, 5 m deep. There are 10 sampling and measuring points at different depths with approximately equal depth distances. Tracing experiment was performed in April 2010 and took place over a time period of approximately two years. Deuterated water was used as conservative tracer, which is known as very useful tracer for this purpose.

For evaluation of flow and transport parameters the software HYDRUS 1-D based on numerical solution of the Richards equation was used. Mualem-van Genuchten model was applied for the parametrization. Deuterium transport was calculated using the advection-dispersion equation. We applied version of HYDRUS, which prevents accumulation of the ^2H concentration at the upper boundary and evaporation has no effect on the ^2H concentration. Estimated soil hydraulic properties in our model are: θ_r was set as 0, θ_s is between 0.38 – 0.51, α between 0.027 and 0.03 (1/cm), n from 1.25 to 1.38, K_s from 4.03×10^{-4} to 5.9×10^{-3} (m/s) and longitudinal dispersivity λ from 4 to 52 (cm). For model optimization we used Nash-Sutcliffe eficiency, which is set between 0.82 and 0.98. In the future these calculations will be used as a basis for characterization of transport processes of organic pollutants in unsaturated zone.

Code of abstract: T3.1.11
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.1. Groundwater modelling in intergranular systems

Using heat measurement to assess Rheraya stream losses to the alluvial aquifer within the Haouz basin (Central Morocco)

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KEY WORDS streamflow, groundwater, recharge, temperature, arid climate

ABSTRACT

Within a hydrological system, groundwater recharge is one of the main parameters to identify due to its role in assessing water budgets and in replenishing aquifers. In arid and semiarid areas, ephemeral streamflow may constitute an important source of groundwater recharge. In our study area, several intermittent streams (wadi) come from the High-Atlas mountains (culminating at 4165 m) and cross the Haouz plain (6000 km^2) from south to north. These wadis, fed by rainfall and snowmelt, contribute to the recharge of the Plioquaternary alluvial aquifer of the Haouz plain, intensively exploited for irrigation and drinking water supply. The present study focuses on the assessment of groundwater recharge from the Rheraya wadi (1.6 m^3/s as mean annual runoff) using heat as a tracer. To this objective, field instrumentation was installed in order to record vertical streambed temperature. The streambed is formed of a mixture of clay, sand and gravel along with boulder-sized material. The analysis of the temperature records and the hydrological data allowed to detect several streamflow events of various intensity. A vertical temperature modelling method was applied to estimate infiltration induced by different floods to the underlying alluvial aquifer. The used code is VS2DHI processed by 1DtemPro. It numerically solves heat and water equation and calculates seepage rates using streambed temperature. The estimated streambed infiltration varies from 7.6 10^{-4} m/day to 2.6 10^{-1} m/day. These relatively low values are in accordance with literature for similar areas. They could be explained by the effect of some cementation of the streambed material. Additionally the infiltration rate deduced values are quite different from those previously applied for water balance calculations of the Haouz alluvial aquifer.

Code of abstract: T3.2.1
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Hybrid meshless karst flow model using the finite volume approach

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KEY WORDS karst flow model, Fup basis functions, finite volume approach, conduit-matrix interaction, verification of the karst flow model

ABSTRACT
Karst aquifers are very important groundwater resources around the world as well as in coastal part of Croatia. They consist of extremely complex structure defining by slow porous medium and usually fast turbulent conduits/karst channels. In this paper novel 3-D hybrid karst flow model is developed. This model uses multiresolution meshless concept based on Fup basis functions with compact support and finite volume framework. Porous matrix is described by linear combination of 3-D Fup basis functions satisfying Darcy law and continuity equation, while conduits are described by linear combination of 1-D Fup basis functions controlling transition between laminar and turbulent flow regimes as well as pressurized or open channel flow conditions. Two sets of these basis functions are independent with own multiresolution description. Porous matrix and conduits are coupled without additional (usually unphysical) parameters satisfying flux continuity through the interface between them. Transient flow simulations are performed through the well-known concept of the method of lines separating spatial and temporal approximation. Using the Fup implicit time integration, coupled nonlinear system of equations is formed at the end of each time step with unknown Fup coefficients for 3-D porous matrix and 1-D conduits. Methodology enables control of numerical error, mass continuity and accurate velocity field that is particularly important for transport karst simulations. Particular difficulty with complex 3-D karst flow model is its verification due to lack of extensive amount of needed input data such as heterogeneity of porous matrix, position and dimensions of conduit network, rainfall and spring discharge data and many others. Presented karst flow model is verified and tested using other numerical results from the literature, laboratory experiments as well as in real examples such as Ombla catchment.

Code of abstract: T3.2.2
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Water inflows into a deep tunnel through the Reunion volcano: observation and modeling

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KEY WORDS volcanic rock, water inflow, transient modelling, analytical solution, island

ABSTRACT
As part of a general project for water allocation, a 7 km-length gallery has been drilled through the shield volcano of the La Réunion Island. During the tunnel drilling, many water inflows have occurred with a maximum total discharge rate close to 2000 l/s. Three aquifer portions have been encountered during the drilling: a first fractured zone between 1200 and 1400 m from the tunnel entrance, a second aquifer between 3000 and 3600 m and finally a third one between 4700 and 5200 m. These water inflows induced delays in tunnel drilling and the total completion of the drilling took almost 10 years. These underground works gave the first opportunity to observe and monitor the geology and hydrogeology deeply into a shield volcano. The available data are the total discharge rate at the tunnel outlet and the drilling progression.
Several modeling approaches have been applied in order to simulate the discharge rate evolution as a function of drilling speed. First, the confined aquifer solution of Jacob and Lohman convoluted for a progressive drilling failed to properly simulate the flow rate in the La Reunion tunnel due to the hypothesis of a radially infinite aquifer which is not met when the drawdown reaches the water table. The classical analytical solution of Goodman for an unconfined aquifer provides a satisfying matching. Nevertheless, this solution corresponds to a very specific case neglecting the recharge rate at the top of the aquifer. The generalized solution of Perrochet and Musy (1992) for an unconfined aquifer with a constant recharge rate is more suited in order to take into account the rainy seasons during the duration of the drilling. Its application is illustrated. It allows computing the length of the depression zone drained by the tunnel. The solution can be applied in order to compute steady-state discharge rate.
The assumptions made in modeling help to increase knowledge of young volcanic aquifers, including the presence of productive aquifer within the lands under 1000 meters of rock cover.

Code of abstract: T3.2.3
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

A conjunctive application of unsaturated zone modelling and field-based methods to assess recharge processes and quantify recharge rates in a coastal, semi-arid, karstic aquifer: Uley South Basin, South Australia

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Keywords: Groundwater recharge; Unsaturated zone; Numerical modelling; Conceptual models; Karstic Preferential flow.

Abstract

Field-based estimates of groundwater recharge are often insufficient for assessing basin-scale recharge, due to the difficulties in accounting for its spatial and temporal variability. Consequently, one-dimensional (1D) unsaturated zone models are commonly advocated to calculate recharge variability, and determine basin-scale inputs. However, despite large conceptual and parametrisation modelling uncertainties, modelled recharge rates are rarely constrained by independent field-based values. In this study, basin-scale recharge to the coastal, karstic, semi-arid Uley South Basin (USB) aquifer (South Australia) is estimated using (i) 1D numerical modelling and (ii) and, the field-based chloride mass balance (CMB) and water-table fluctuation (WTF) methods. The field-based methods were modified from traditional applications to better represent the coastal conditions of USB. The 1D unsaturated zone model LEACHM was adopted in an integrated-GIS framework to simulate temporal and spatial variations in rainfall recharge according to depth to water table, topographical slope, substrate characteristics and vegetation type. The results show that the modelled combinations of unsaturated zone lithologies and representations of karstic preferential flow produce spatially- and temporally-averaged recharge rates consistent with estimated recharge using the modified CMB. Consistency between simulated and field-based transient recharge, inferred from WTF, was obtained for selected conceptual representations of preferential-flow karstic features. Field-based methods that produce integrated recharge estimates proved to be essential in assessing conceptual models and constraining model predictions, especially when very few unsaturated zone data are available to parameterise and validate the 1D model. The successful combination of field-based and modelling approaches imparts improved confidence in both methods, when used in combination, for basin-scale recharge estimation.

Code of abstract: T3.2.4
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

A hydrological model for predicting flooding in geographically-isolated karst wetlands

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KEY WORDS wetland, modelling, karst, turlough, Ireland

ABSTRACT

There is growing recognition of wetlands as providers of valuable ecosystem services such as climate regulation, biodiversity, flood control and ecotourism. However, anthropogenic and climatic pressures have contributed to the widespread degradation and destruction of these habitats. Despite this, Ireland still contains one of the highest concentrations of wetlands in western Europe. Ephemeral geographically-isolated, groundwater-fed lakes (turloughs) are a common feature of Ireland's extensive karstic limestone terrains. The temporary nature of flooding gives rise to a characteristic ecology, protected as a Priority Habitat in the EU Habitats Directive (92/43/EEC). In additional to their ecological importance, turloughs are the primary form of groundwater flooding in Ireland. Understanding the hydrological controls influencing these wetland systems is vital for their effective management and conservation. For this reason, a flexible reservoir modelling methodology was developed to quantify hydrological functioning using readily derivable climatic variables. The model used regional rainfall and evapotranspiration data to produce wetland inundation time series and depth-duration curves for sites across a spectrum of flooding regimes. Model fitting was carried out using a generalised sensitivity analysis approach based on Monte Carlo simulations, allowing the estimation of parameter sensitivity and uncertainty. Model efficiencies ranged from 80-93% for flood volume and 9095% for flood duration, indicating the model provided a good representation of hydrologic functioning for all sites. The components of the reservoir model, namely equations governing recharge and drainage, provide an insight into the mechanisms determining wetland hydrology and validated the basic conceptualisation of turloughs operating as reservoirs within the karst flow network. The model was also used to reconstruct long-term hydrological time series, allowing for the first-time analysis of the trends and variability in hydrological metrics key to ecosystem structure and composition (e.g. flood duration, frequency).

Code of abstract: T3.2.5
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Groundwater flooding in a lowland karst network in response to extreme rainfall and tidal event synchronicity

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KEY WORDS karst, transfer function model, groundwater flooding, tide

ABSTRACT

The objective of this research was to develop a black box transfer function model of a lowland karst network in order to assess groundwater flooding in the area in response to combinations of extreme rainfall and tidal events. The study has focused on a lowland karst network in the west of Ireland fed by allogenic runoff from low permeability Devonian mountains and discharges into a bay below mean sea level. The temporal dynamics of localised groundwater-surface water interactions have been studied for several years to yield information about the nature of the hydraulic connections beneath the ground. From this a deterministic hydraulic / hydrological distributed pipe network model of the system has been developed. This model predicts the outflow from the main spring into the sea (which had not been possible to measure continuously) but has been validated against discharge estimates using conductivity profiles and radon concentrations.

In response to severe flooding events in November 2009 and December 2015, this current research has now characterised the hydrogeology of whole karst network by a single transfer function to investigate the impact of the two main drivers on flooding (rainfall and tidal level) in the area. The data used to develop the black box model was time series of flooded storage, rainfall and tide levels (all from monitoring) and the spring outflow discharge (from the calibrated pipe-network model described). Frequency analysis of the data sets was then carried out using Fast Fourier transform analysis and a transfer function based upon a discrete wavelet function has been derived to characterise this inherently non-stationary behaviour of the flooding in the karst system. The results suggest that the extent of flooding is related to the synchronicity of heavy rainfall and perigean (i.e. maximum) spring tides. Historical flooding of the area back to the 1900s have then been compared with the predictions of the model. This knowledge can be used to make more reliable flood management predictions and mitigation strategies in the future in order to help to protect local communities.

Code of abstract: T3.2.6
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

KMC: "Karst Modelling Challenge", a comparison between modelling approaches in karst

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KEY WORDS Karst, modelling, comparison, international, test-site

ABSTRACT

The range of modelling approaches and techniques applied to karst is large. In many cases the modelling consists in fitting some input/output data with more or less physical background in the models. Even if the fitting of the modelled data to the observed one seems reasonable in most cases, it is difficult to assess if the model provides good results for the good reasons. In other words, it is very difficult to assess the limits beyond which model results cannot be extrapolated. As many models are used to assess the effect of climate change, including extreme conditions, knowing the limits of our models is an ethical necessity.

The idea is to provide a set of data from a well-known test-site to the modelling teams. The first challenge is to work on precipitation-discharge modelling. Any team is invited to produce his best model with the same data set. The results of the respective modelling groups will be compared and discussed. The first elements of this comparison will be presented at the conference.

As the test-site is well known, results of the respective models will be compared to complementary data, such as sub-catchment discharge rates, and heads at various places in the catchment. Results of tracing experiments and of natural tracers will also be compared in the future.

The program is based so far on the good willing of modelling groups. It is an initiative of the Karst commission of IAH.

Code of abstract: T3.2.7
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Geological considerations in modelling bedrock aquifers

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KEY WORDS - conceptual model; permeability; groundwater model; lithology

ABSTRACT
An important step in modelling bedrock aquifers is building a conceptual geological model of the processes that resulted in the present permeability distribution. Pertinent questions include: Is flow predominantly through the pores, with permeability being determined by facies variation? Or is flow predominantly through fractures, and if so what are the apertures and spacing of the fractures? Are the fractures aligned along bedding planes, or produced by tectonic forces? What role if any has weathering had on enlarging fracture apertures?
These questions were addressed in a paper that reviewed the reasons for the wide differences in permeability between the five major lithologies, represented by limestone, sandstone, shale, basalt and granite (Worthington et al., Earth-Sci. Rev., 2016). Flowmeter data from 96 wells showed that all measurable flow in most wells was just from fractures, and the fraction of flow from fractures (Q) followed an exponential distribution Q=116 exp (-0.797n), where n is the rank of the fracture. In both carbonates and silicates, weak correlations were found between permeability and physical properties such as porosity, tensile strength, compressive strength, and tectonic setting. Much stronger correlations were found between permeability and both solute concentration and dissolution rate. This suggests that weathering or alteration (principally dissolution) plays an important role in determining the permeability of most bedrock aquifers. Weathering is usually greatest closest to the surface, so permeability generally reduces with depth. This is particularly notable in carbonate and crystalline lithologies. The role of weathering in enhancing permeability in carbonates is well understood, and the rapid reaction rates mean that leakage beneath dams constructed on limestone can increase greatly on a time scale relevant to humans. The results also suggest that weathering is a major factor in enhancing permeability in silicate aquifers. For instance, shale is principally composed of low-solubility quartz and clay minerals, and the permeability in shale is much lower than in other silicate rocks, which all have higher solubilities. Thus the results show how weathering in an important process in determining the permeability of bedrock aquifers.

Code of abstract: T3.2.8
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Spatio-temporal interpolation of water table depths in a conservation area at Bauru Aquifer System (SP/Brazil)

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KEY WORDS - geostatistics, time series, ST variogram, ST kriging, monitoring

ABSTRACT
Spatio-temporal (ST) variability is a trick characteristic of monitoring data when we decide to model space and time together. In general, monitoring data have both indexation with space varying in meters, kilometers (a measure of distance) and time varying in days, months, years, centuries (a measure of existence). The obvious link between space and time is many times ignored by researchers due its difficult to join variabilities that happen in different dimensions in one single model. ST geostatistics provides an interesting approach to solve this question, proposing to model time as an anisotropic ratio of the spatial variability using covariance functions. From spatial and temporal correlations, it is possible to predict values at points from neighbouring observations and make predictions in between observation times. Once the ST variability is modeled using ST variograms, it is possible to perform a ST interpolation using ST kriging. As result, time frames containing spatial scenarios of specific dates can be mapped and used for groundwater manage and planning purposes. The difference of these maps from traditional kriging maps is the consideration of past variabilities gathered from the input time series in the interpolation process. The aim of this work was analyze water table depths monitoring data using the ST geostatistics approach. Water table depths monitoring data was collected from September 2014 to April 2017 in a conservation area in Águas de Santa Barbara/SP-Brazil. The Santa Barbara Ecological Station (EEcSB) is a 15 km^2 area with natural Cerrado vegetation and some reforest with pine and eucalyptus trees. EEcSB limits are under the domains of Bauru Aquifer System, a Cenozoic sandstone sedimentary rock 60-m thick limited in the bottom with basaltic volcanic rock and in the top with more recent geological covers. This aquifer is one of the major groundwater sources of central-west part of São Paulo State, covering almost half of its territory. The water table is monitored semi-monthly in the EEcSB area at 65 piezometers near the main drainage channels. As result we present two scenarios, from the wet and from the dry seasons and discuss its differences. The influence of ENSO (El Ninõ South Oscilation) phenomena during 2016 on water table depths variation is also approached, focusing monitoring strategies.

Code of abstract: T3.2.9
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Improved understanding of spatio-temporal controls on regional scale groundwater flooding using hydrograph analysis and impulse response functions

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KEY WORDS Chalk, groundwater flooding, cluster analysis, impulse response function, standardised index

ABSTRACT

Controls on the spatio-temporal extent of groundwater flooding are poorly understood, despite the distinctively long duration of groundwater flood events. A novel approach has been developed using statistical analysis of groundwater level hydrographs and impulse response functions (IRFs) and applied to the 2013/14 Chalk groundwater flooding in the English Lowlands. A new standardised index of groundwater flooding devised is applied to monthly groundwater levels for 26 boreholes. These standardised series have been grouped using k-means cluster analysis and the cluster centroids cross-correlated with the Standardised Precipitation Index (SPI) accumulated over time intervals between 1 and 60 months. This analysis reveals two spatially coherent groups of standardised hydrographs which respond to precipitation over different time-scales. IRF models of the groundwater level response to precipitation are estimated for three representative boreholes in each group. The IRF models corroborate the SPI analysis showing different response functions between the groups. Identical precipitation inputs applied to each of the IRF models and produce substantial differences between the hydrographs from each group. It is suggested this is due to the hydrogeological properties of the Chalk and of overlying relatively low permeability Superficial Deposits (such as clays and tills), which are extensive over one of the groups. The overarching controls on groundwater flood response are concluded to be a complex combination of antecedent conditions, rainfall and catchment hydrogeological properties. These controls should be taken into consideration when anticipating and managing future groundwater flood events. The approach presented is generic and parsimonious and can be easily applied where sufficient groundwater level and rainfall data are available.

Code of abstract: T3.2.10
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Numerical modelling as a tool to improve conceptual models: the case study of a regional hydrothermal system in NE Italy

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KEY WORDS - numerical modelling, geothermal resource, damage zone, Euganean Geothermal System

ABSTRACT
The construction of a reliable conceptual model is a crucial aspect in modern hydrogeology. A detailed conceptual model can be used as a starting point for a subsequent numerical model aimed to plan a sustainable utilization of the hydrogeological resource. Usually, conceptual modelling of a regional, deep hydrothermal system is puzzling due to its geological complexity or the lack of exhaustive data over a wide area. In this peculiar case, numerical modelling can be used to validate the conceptual model evaluating some aspects of the flow. The Euganean Geothermal System in Veneto Region (NE Italy) is the subject of still ongoing studies because the naturally emerging thermal water (temperature from 65°C to 86°C) represents a profitable resource for the touristic industry, impacting the regional economy. The thermal water is of meteoric origin, and infiltrates in Veneto Prealps to the north of the main geothermal area (i.e., Euganean Geothermal Field, EGF). The water flows for 100 km in the subsurface of the central Veneto heating up to 100°C by the crustal heat flux. The conduits hosting the fluid flow are identified in the damage zones of the Schio-Vicenza fault system (SVFS), while the outflow in the EGF is associated to an interaction zone between the SVFS faults. The stress concentration produces a localized high secondary permeability, maintaining the aperture of the fractures. This work aims to validate this conceptual model through 3D coupled flow and heat transport numerical simulations unravelling the impact of fracture networks on the regional-to-local groundwater circulation. A reconstruction of the geological setting, including the high permeable zones, is performed. The distribution of the hydraulic and thermal properties is reproduced using the equivalent porous medium approach and discrete elements. The modelled temperature in the EGF reservoir results higher than in the surrounding areas, according to the measured temperature distribution. This local increase is produced by the rising of deep-seated groundwater driven by the local fractures. The results validate the proposed conceptual model. In addition, they suggest that the temperature in the deeper part of the reservoir could be higher than the expected value, opening a new scenario for the utilization of the thermal resource.

Code of abstract: T3.2.11
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Modeling of regional land subsidence due to aquitard drainage in Konya closed sub-basin, Turkey

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KEY WORDS confined aquifer, groundwater flow modelling, subsidence

ABSTRACT

Land subsidence due to aquitard drainage is a common geo-hazard in the Konya closed sub-basin, central Anatolia, Turkey. The groundwater in the confined Neogene aquifer of the basin is the sole source of irrigation water. The Neogene aquifer includes lacustrine carbonates with extreme secondary porosity and permeability development due to karstification and low-permeability interbeds rich in clay and silt. As a consequence of over-pumping, regional groundwater head in the basin has declined with a rate of about 1 m/year since early 1980s. Overuse of the groundwater has accompanied also by the land subsidence which is mostly subtle but also includes increasing number of sudden collapse formations (obruks in Turkish). These collapse dolines develop due to ceiling collapse of large submerged karst cavities because over-pumping of groundwater eventually decreases the groundwater head and its buoyancy. The formation of obruks started to become a life and property threatening geo-hazard during the last decade. The location and frequency of obruk formations are linked closely with the aquitard discharge zones that appears to correspond to the areas where groundwater abstraction is extensive and the confining layer over the Neogene aquifer is thin.
MODFLOW numerical groundwater flow model coupled with subsidence (SUB) package is used to infer the effect of long term groundwater abstraction on the spatio-temporal variation of subsidence rates. The flow model comprising of an 8390 sq. km large part of the subbasin was run in transient mode for 30 years between 1985 and 2016. The model includes the confining Plio-Quaternary lake sediments on top and the confined Neogene aquifer at the bottom. Interbeds (aquitard) are placed in Neogene aquifer to simulate the subsidence. Model calculated subsidence rate of 27 mm/year for 2010-2013 is in agreement with the geodetic observations of 22 mm/year. Results of this study show that the areas of potential obruk formation in the future can be identified by numerical aquitard drainage modeling which has to be supplemented by spatio-temporal geodetic data.

Code of abstract: T3.2.12
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Use of numerical modelling to test hypothesis on the hydrogeological conceptual models in a complex aquifer: Riardo Plain (Southern Italy)

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KEY WORDS - Volcanic aquifer – carbonate mineral aquifer – 2D model – hydrogeological conceptual models – Predictive models

ABSTRACT

Complex hydrogeological systems require the application of different methods to better understand their behaviour. A regional hydrogeological research was developed on the Riardo Plain aquifer (Southern Italy) which is a fundamental resource for human consumption as well as for mineral waters bottling. A volcanic and a carbonate aquifer can be distinguished at regional scale. The multilayered volcanic aquifer presents a radial flow from the Roccamonfina volcano towards gaining streams and it is recharged by direct infiltration. Regional information about the carbonate aquifer are not available, since monitoring points and tapping wells are mainly placed in the Ferrarelle mineral bottling plant. Recharge of the carbonate aquifer is likely to upflow from the deep reservoir, but no direct information are available about rates and spatial distribution.

Groundwater budget calculation highlighted a significant water deficit, apparently with no effects on the aquifer quantitative state. These results suggest the presence of a deeper recharge through the carbonate aquifer.

A local preliminary 2D model was built on a small area with a high quantity of data. The finite element code FeFlow 6.2 was used and calibration was performed via inverse modelling through FePest (PEST code). Aim of the 2D numerical model was to test different hypothesis of possible bottom recharge rates. More than a confirmation of the preliminary conceptual model, the numerical model was used to highlight its weaknesses. Different recharge scenarios were supposed and the 2D model was calibrated over horizontal, vertical hydraulic conductivity and specific storage, according to the weekly head measurements recorded in the 2003/04 in two monitoring wells located in the Ferrarelle plant, tapping the volcanic and the mineralized carbonate aquifers. After the calibration, the simulation time was extended to 15 years (2000/14) to evaluate the behavior of the simulated heads. Results showed a comparable error (simulated-observed heads residuals) between the calibration series (2 years) and the validation one (13 years) without any divergence in time. The hypothesis tested in the 2D model will be included as information to limit the number of unknowns in a complex highly-parametrized regional 3D model. The 3D model will be calibrated and validated in the attempt to constraint the ranges of the applicable carbonate recharge, information which can be hardly provided by direct measurements.

Code of abstract: T3.2.13
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Sensitivity analysis of a distributed karst hydrological model at a Floridian karst aquifer

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KEY WORDS karst water resources, karst aquifer, distributed simulation, sensitivity analysis

ABSTRACT
Karst aquifers are an important source for clean drinking water in many regions around the globe. However, their distinctive heterogeneity and anisotropy poses a major challenge for water management. Hydrological models are a common tool to assess the impact of climate or land use changes on karst water resources. Often those models are required to provide spatial information of karst aquifer levels and groundwater flow in the vicinity of water supply wells. This work presents the first results of the sensitivity analysis of a numerical karst groundwater simulation model (an enhanced version MODFLOW-CFP; Reimann et al., 2014) to a karst aquifer in Florida (US). Previous research (Kuniansky, 2016) showed that the explicit consideration of karst properties within MODFLOW-CFP improved the simulation of storm events. In this study we build up on these previous experiences and apply enhanced parameter sensitivity analysis to better understand the simulated processes and fluxes and to prepare the model to also simulate the solute transport behavior of the aquifer.

Kuniansky, E.L., 2016. Simulating groundwater flow in karst aquifers with distributed parameter models—Comparison of porous-equivalent media and hybrid flow approaches. US Geological Survey.
Reimann, T., Giese, M., Liedl, R., Maréchal, J.C., Shoemaker, W.B., 2014. Representation of water abstraction from a karst conduit with numerical discrete-continuum models. Hydrol. Earth Syst. Sci. 18, 227–241. doi:10.5194/hess-18-227-2014

Code of abstract: T3.2.14
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

DNA nanotracers in characterization of stimulation enhanced pore space in fractured rock

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KEY WORDS tracer tests; fracture-dominated system; rock mass stimulation

ABSTRACT
Groundwater flow in fractured media is heterogeneous and takes place in structures with complex geometry and scale effects. As a consequence, the characterization and modeling of the groundwater flow that is essential in many hydrogeological and geo-engineering situations is technically challenging. Tracer tests are routinely used to characterize attributes of flow paths, and are usually conducted using one of several commonly available solutes. However, they are limited in number, which becomes problematic when multi-tracer or repeat tests are to be conducted without tracer interferences. Novel DNA nanotracers, which consist of silica particles encapsulating DNA fragments, can overcome this problem as they can be produced in a virtually unlimited number of varieties.

In this study, we use DNA nanotracers to investigate changes in the connected pore space of a fractured granodiorite resulting from hydraulic stimulation operations. The stimulated part of the rock mass has a scale of decameters and is located in the Deep Underground Geothermal Laboratory (DUG-Lab) at the Grimsel Test Site in the Swiss Alps. Tracer tests were conducted during circulations performed before and after the stimulation operations to characterize the predominant flow paths. Generally, the tests were conducted with both DNA and solute dye tracers to permit a comparison of the results. Tracers were injected at multiple intervals in the injection borehole, and the concentration histories of the individual tracers (both the variously-tagged DNA and the solute dyes) were recorded at outflow points in production boreholes and in galleries. The concentration histories were converted to residence-time distributions, which were then analysed using the standard advection-dispersion equation (ADE), and other approaches that include other mechanisms, such as multirate mass transfer (MRMT) processes. The distinctive transport processes of the DNA nanotracers and the solute dye tracers are thus modelled, with advanced characterization of the connected pore space.

Code of abstract: T3.2.15
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.2. Groundwater modelling in fractured systems

Numerical modeling of reactive transport in fractured porous media: Application to the Aquifer Storage and Recovery project in Qatar

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KEY WORDS Fractured media – Reactive transport – ELLAM – SNIA

ABSTRACT

The fluid flow and solute transport through fractures in rocks are processes that have importance for many areas of the geosciences, ranging from groundwater hydrology to petroleum engineering. It is well known that fractures play an important role in flow and transport processes through geologic formation and number of environmentally relevant problems require the analysis of contaminant transport in subsurface systems.

In this work, we develop an efficient numerical tool based on Eulerian – Lagrangian Localized Adjoint Method (ELLAM) combined with the Sequential Non Iterative Approach (SNIA) to accurately simulate reactive transport in fractured media. Unlike the classical discrete fracture model where (n-1)-dimensional elements are used to represent the fractures, we use the Single Continuum approach (SC) where the cracks are explicitly represented and the entire domain is discretized using meaningful n-dimensional elements. With SC approach the exchanges at the interface between fractures and porous matrix can be catch and treat properly. Otherwise, the numerical difficulty arising from spatial discretization of the fractures can be overcome by using our ELLAM scheme which is not constraint to CourantFriedrichs-Levy criterion. Moreover, ELLAM is also known to be well adapted for advection-dominated problem as the transport processes occurring in the fractures.

In this study we show, for the first time, how ELLAM and SNIA can be efficiently combined to simulate reactive transport in fractured media. The performance and accuracy of the developed model are compared against those of an existing numerical model based on Discontinuous Galerkin (DG) method. Two test cases, dealing with reactive transport in fractured porous media and involving chemical reactions with only aqueous species or both fixed and aqueous species, show the superiority of the ELLAM model compared to the DG model.

This work contribute to the Aquifer Storage and Recovery (ASR) project of Qatar which aims at artificially storing water in the aquifer for future use by developing an efficient and accurate model for reactive transport in fractured porous media.

Code of abstract: T3.3.1
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

Reducing uncertainty in integrated hydro(geo)logical models by incorporating various novel, spatially distributed measurements

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KEY WORDS - mountain hydrology; numerical modelling; climate change; uncertainty

ABSTRACT
The response of key elements of the alpine hydrological system to climatic changes, such as snowpack and glacier storage, is increasingly evident. However, the responses of vegetation, geomorphology, soils and groundwater - which can also affect the quantity and timing of water availability downstream - are likely to be more subtle, and so must be predicted with complex, integrated groundwater-surface water hydrogeological models. In mountainous regions, strong elevation gradients drive considerable spatial variability in focings and physical processes. Yet, such spatial patterns (e.g. in precipitation, temperature and evaporation, land surface parameters, 3D subsurface hydrological properties, etc.) are rarely explicitly represented in such physically-based numerical models. Here, we will discuss new approaches to incorporate a variety of inter-disciplinary, spatially-distributed datasets in model setup, calibration and evaluation. The data considered will include groundwater noble gas concentration measurements, geological fields, and downscaled meteorological reanalysis products. Data integration will be carried out using the PEST parameter estimation and uncertainty tools, which enable the outstanding question of which datasets bring about the largest reductions in predictive uncertainty to be addressed. This information could prove extremely useful in making predictions in less-studied regions. The resultant model will be applied to estimate the integrated system response to various hypothetical scenarios such as changed meteorology, permafrost distribution, and treeline advancement across the study region (Nant/Anzeindaz, Vaud, Switzerland), thereby improving assessments of climate change impacts upon the key ecosystem service of water provision.

Code of abstract: T3.3.2
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

Regional Groundwater Model Constrained with ^{14}C Dating: A Case Study in the Endorheic Cretaceous Basin of Tsagaan Els, Mongolia

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KEY WORDS Arid Environment, Groundwater Residence Time, MODFLOW, Radiocarbon, Regional Modeling

ABSTRACT

The Tsagaan Els basin is a very large endorheic basin located in the Gobi desert (Southern Mongolia). Its central part, ~16,000 km², is filled with Cretaceous sedimentary rocks and is crossed by the North-Zuunbayan fault, which determines two partially-connected hydrogeological sub-basins: Zuunbayan and Unegt. Two roll-front uranium ore deposits have been discovered in these sub-basins by Areva and its subsidiary COGEGOBI, and the regional aquifers have been carefully surveyed for several years. This study presents the regional groundwater model that was implemented with Visual MODFLOW 2009 to better understand this multilayer aquifer system, where high-salinity groundwater can be found (up to 20 g/L). The model was subdivided into two parts, one for each sub-basin, and calibrated through PEST™ with data obtained from Areva's piezometric network. Numerical estimates of groundwater age were also obtained for the entire basin and punctually compared with radiocarbon ages to validate the model. The water budget obtained with this model indicates a low recharge around 1.7 mm/a and an important transfer of water from Unegt sub-basin to Zuunbayan sub-basin occurring at a few main springs along the North Zuunbayan fault. Around 65 % of water is lost by evaporation during this transfer. The remaining part seeps through and later evaporates in the depression located at the center of Zuunbayan sub-basin. An annual potential evaporation rate ranging between 1,450 and 1,700 mm/a is needed to account for the absence of permanent surface water on this terminal discharge playa, which remains currently dry. The groundwater age is on average 46 ka and 24 ka for the Unegt and Zuunbayan sub-basins, respectively, with large uncertainties linked to the hydrodynamic parameters estimation. Groundwater radiocarbon dating was conducted on Zuunbayan sub-basin and has proved to be a useful tool to better constrain the calibration method in basins where this type of geochemical approach is applicable. This work has been supported by a CIFRE/ANRT doctoral grant n° 2014/0572.

Code of abstract: T3.3.3
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

Regional recharge estimation by applying a Genetic Algorithm to various groundwater balance methods

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KEY WORDS - Recharge, Saturated Volume Fluctuation, Cumulative Rainfall Departure, EARTH Method, Genetic Algorithm

ABSTRACT
The most popular recharge assessment method applied in South Africa is the Chloride Mass Balance (CMB) method. The reason for the popularity is the fact that a recharge estimation is based on the chloride concentration in the groundwater and the rainfall. When multiple boreholes exist, the harmonic mean of the borehole chloride concentrations is used to suppress the higher chloride concentrations. The two major problems with the CMB method is that rainfall chloride values are seldom measured and the regional geology can naturally cause elevated chloride values in groundwater.
Various recharge methods based on a groundwater balance exist. The change in storage is expressed as a change in water level through the use of the aquifer specific yield and aquifer surface area. The modelled water level response is then compared with the observed water level response and a curve fit is carried out. Typical fitting parameters in the water balance are the recharge, specific yield, lag time and net-flow through the aquifer with rainfall driving the water balance model.
Popular groundwater balance formulations used to estimate recharge include the Saturated Volume Fluctuation (SVF), Cumulative Rainfall Departure (CRD) and the Extended model for Aquifer Recharge and soil moisture Transport through the unsaturated Hardrock (EARTH) method. Since each of these methods require a manual procedure to do the best curve fit, it becomes a tedious process over large study areas containing many monitoring boreholes. The focus of this paper is the development and application of a genetic algorithm that automatically performs curve fits for each of the above-mentioned methods. Conventional methods used in automatic curve fit applications require an accurate estimation of initial values for the fitting parameters. This is not a requirement for genetic algorithms thereby making it an attractive solution. Genetic algorithms can also be used in parameter estimation of more complex functions. This makes it a better alternative than other evolution based methods.
The application of the genetic algorithm is demonstrated by making use of data from South Africa's National Groundwater Archive and calculating regional recharge over extended areas.

Code of abstract: T3.3.4
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

Direct simulation of environmental tracer (^{4}He, ^{3}H, ^{14}C, $\delta^{18}O$, $\delta^{2}H$) transport in regional-scale aquifers at the 0-40 kyr timescale

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KEY WORDS Numerical modelling, Environmental tracers, Paleowater

ABSTRACT

Environmental tracers serve as tools for the investigation of flow and transport processes in hydrological systems. The combined interpretation of multiple tracers enhances understanding as processes act differently on different tracers. Measured tracer concentrations can be compared to numerical simulations of tracer transport that include physical processes such as advection, diffusion, dispersion, decay and production. This study shows how the transport of various environmental tracers can be simulated using a numerical model in order to improve the understanding of a large, complex system through various timescales.

We used a set of environmental tracers to investigate the evolution of a regional-scale groundwater flow system in South West Denmark. The investigation area is located in a paleo-glacial foreland basin composed of glacial sediments deposited during the Pleistocene. Climatic and hydrodynamic conditions imposed by the last Scandinavian Ice sheet affected the entire region. Samples were collected for analyses of atmospheric noble gases (Ne, Ar, Kr, Xe), helium isotopes (^{3}He, ^{4}He), stable isotopes of water ($\delta^{2}H$, $\delta^{18}O$), tritium (^{3}H), and carbon isotopes (^{13}C, ^{14}C). Noble gas temperatures suggest that part of the samples recharged during conditions with significantly lower temperatures. This interpretation is in agreement with the results of ^{14}C, $\delta^{2}H$ and $\delta^{18}O$ analyses. The transport of ^{4}He, ^{2}H, ^{18}O, ^{14}C and ^{3}H was simulated using the MODFLOW and MT3DMS codes and while accounting for the effects of production, decay, dissolution, diffusion and mixing. Calibration of the numerical model to observed tracer concentrations enabled improvements to the conceptualisation of the groundwater flow system. For example, parameter ranges for hydraulic conductivities and porosities were better constrained, and recharge areas and fluxes were identified. This study highlighted processes that influenced tracer transport, such as diffusion between mobile/immobile domains, and provided deeper insights into flow and transport processes.

Code of abstract: T3.3.5
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

The worth of unconvetional observations in groundwater model calibration

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KEY WORDS unconventional observations, surface water-groundwater interactions, model calibration, argon-37, noble gases

ABSTRACT

The characterization and simulation of the interactions between surface water and groundwater require observations of hydrological state variables and flow processes. While the latest generation of physically-based flow models allows the integrated simulation of all relevant hydrological processes, the current modelling practice is far from adequate to provide reliable predictions. Numerous studies suggest that the main reason for this limited predictive capability is that the complex nature of surface water – groundwater systems cannot be sufficiently described and constrained by only taking into account the 'classical' hydrogeological observations of surface water discharge and hydraulic head.
To overcome this problem, alternative, unconventional observations should be considered for flow model calibration, for example tracer or exchange flux measurements. With the appropriate modelling and calibration tools unconventional observations can not only be successfully included in flow model calibration, but with the right tools it is also possible to quantify the information content of unconventional observations towards reducing the predictive uncertainty of the flow model. We present such a modelling and uncertainty analysis framework, and provide examples where observations of natural environmental tracers (atmospheric noble gases and the novel Argon-37 method) were successfully used to better inform a surface water-groundwater model of an important drinking water station in Switzerland.

Code of abstract: T3.3.6
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

A spatial distribution of chemical and isotopic parameters of groundwater in Slovenia

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KEY WORDS chemical composition; groundwater; spatial distribution; stable isotope; Slovenia

ABSTRACT
Groundwater is a globally important, valuable and renewable resource. Its chemical status has a decisive influence on the applicability of groundwater as a drinking water resource and on the possibility of groundwater use for technological or recreational purposes. Groundwater chemical composition depends on numerous factors, natural as well as antropogenic. The lithological composition of rocks is definitely one of the most important natural factors, and also several other factors e.g. climatic conditions, type of vegetation cover, etc. Among antropogenic influences, urbanization together with agricultural exploitation and various point source loads (municipal waste disposal facilities, industrial plants, sewer system and waste water treatment plant discharges). In spite of the large number of routine hydrochemical analyses of individual water sources, neither a comprehensive overview of groundwater hydrochemical properties nor a detailed interpretation of groundwater chemical composition, especially from the point of view of their origin, have been made in Slovenia.

Therefore the main aim of the research was to find and create the most appropriate algorithm of the spatial model for groundwater chemical composition in Slovenian aquifers, which will enable the prediction of natural chemical characteristics of groundwater in areas with heterogeneous geological structure. For this purpose, sampling for groundwater chemical (Ca^{2+}, Mg^{2+}, HCO_3^- and NO_3^-) was carried out at 262 sampling points, while for isotopic ($\delta^{18}O$) analysis at 86 sampling locations in various aquifers between 2009 and 2011. A number of spatial data, i.e. the altitude of the terrain, climate characteristics, lithological structure and land cover were used to produce thematic maps of groundwater chemical and isotopic composition. Three different methods, i.e. ordinary kriging, multiple linear regression, and artificial neural network - multilayer perceptron, were used to predict different chemical parameters in groundwater. Multiple linear regression was found to be the most significant model for predicting the distribution of $\delta^{18}O$ in groundwater, as well as for carbonate parameters (Ca^{2+}, HCO_3^-) in groundwater, while artificial neural network – multilayer perceptron shows the best results for Mg^{2+} prediction in groundwater. The most successful method for the prediction of NO_3^- in groundwater has proved to be multiple linear regression.

Code of abstract: T3.3.7
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.3. Using unconventional observation data in hydrogeological modelling

Numerical simulation of dissolved CO_2 migration considering geological heterogeneity in a shallow aquifer at EIT site, Korea

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KEY WORDS
Numerical simulation, Dissolved CO_2 migration, Heterogeneity, Multi-depth cross-borehole pumping tests, Shallow aquifer

ABSTRACT
In recent years, there has been increasing interest in Carbon Capture and Storage (CCS) to reduce CO_2 emission for managing climate change in many countries. Since one of main concerns associated with CCS is possibility of CO_2 leakage into shallow aquifers, shallow depth groundwater monitoring is necessary for evaluation of environmental impacts. Establishing efficient monitoring system of the CO_2 leakage process in the shallow aquifer, a controlled test bed, EIT (Environmental Impact evaluation Test facility on seepage of geologically stored CO_2), was constructed in the Eumseong area of Korea. Since understanding CO_2 migration through preferential flow paths in heterogeneous aquifers is important, multi-depth hydraulic conductivities were estimated from several cross-borehole pumping tests with an injection well and multi-depth monitoring wells. On the basis of the obtained hydraulic conductivities in the study area, three-dimensional numerical models were constructed to simulate the behavior of injected CO_2 (liquid phase) in the heterogeneous porous media. The results demonstrate that the dissolved CO_2 plume transport under the influence of heterogeneity at the EIT site. Based on this study, our numerical simulation will be applied to support the monitoring system design for a long-term injection test.

Acknowledgement: Financial support was provided by “R&D Project on Environmental Management of Geologic CO_2Storage”from the KETI (Project Number: 2014001810003).

Code of abstract: T3.4.1
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Numerical modeling of the groundwater pollution and contaminant plume migration from the industrial waste site in Stalowa Wola (South Poland)

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KEY WORDS industrial waste site, acidic sludges, toxic metals, plume migration, numerical modeling

ABSTRACT
Numerical modeling have become a basic tool for environmental risk assessment at contaminated sites, due to the presence of contaminants' sources and emission of toxic substances to the environment. The role of numerical modelling increase when the presence of waterworks' on the plume pathway occurs or lack of data from the monitoring studies and hence the impossibility of establishing the actual environmental pollution and predict its changes in time.
Problem presented in the paper is related to the threat to Quaternary groundwater caused by sediment ponds, where the industrial waste from the "Stalowa Wola" steelwork, mainly acidic sludge's from metal working processes but also resides from paint and varnish removal and lubricants, engine oils and minerals, were deposited. The waste of about 150 thousands Mg were deposited together in 5 landfills with on area of 1.5 ha, none of which is isolated to prevent leaking the contaminants into the groundwater or the isolation is insufficient or have been destroyed.
Deposition area of highly toxic waste from the "Stalowa Wola" steelwork activity is located within the MGB No. 425 Dębica – Stalowa Wola – Rzeszów in close proximity to the wells supplying inhabitants of the Stalowa Wola city in drinking water. Nearby the pollution source there are also located other waterworks, used in the food industry.
Contaminants migration from sedimentary ponds, including the toxic trace elements (Cd, Cu, Mn, Ni and Zn) and organic substances poses a significant threat to exploited Quaternary groundwater. Due to the mismanaged groundwater monitoring and degradation of piezometers network, there is insufficient data available for a reliable assessment of current contaminant plume status in the close area of sediment ponds and to determine its extent.
The numerical hydrogeological model of the Stalowa Wola region was created to map the conditions and groundwater flow at the site. However, its main objective was to provide a reliable assessment of extent and migration time of contaminants from the sediment ponds to nearby waterworks' wells and to propose the remediation of contaminated groundwater or their interception using a hydraulic barrier consists of drainage wells.

Code of abstract: T3.4.2
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Role of connectivity when modeling solute transport nearby pumping wells in heterogeneous media

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KEY WORDS: pumping wells, solute transport, heterogeneity, uncertainty, upscaling

ABSTRACT

Predictions of the behavior of the solute plumes in heterogeneous aquifers are required for risk assessment and remediation tasks. It is widely accepted that these predictions are complex and uncertain, mainly because of the limited characterization of aquifers' hydraulic properties, which randomly vary in space (and sometimes in time).

Stochastic hydrogeology attempts to overcome some of these difficulties, by means of effective conceptual models and/or effective parameterization of spatio-temporally variable properties of the subsurface. Examples are the use of Monte Carlo analysis embedding stochastic simulations based on two- or multiple point geostatistical models, the use of scale-dependent effective models or nonlocal solutions, such as multi-rate mass-transfer, continuous time random walk or fractional models.

Nearby pumping wells, solute transport is strongly influenced by the radial flow configuration. The presence of connected features, vertical mixing and the local changes in aquifer pressure can induce unexpected results, such as triggering anomalous transport and tailing observed on breakthrough curves from tracer tests experiments. Nearby pumping wells, most of the traditional stochastic theories based on ergodicity and stationarity assumptions cannot be easily applied, because transport is intrinsically non-stationary and quite often transport is not ergodic.

This contribution provides an overview of recent results from laboratory and numerical analyses focusing on solute transport nearby pumping wells (Pedretti 2013; 2014; 2016; Molinari 2015). In these analyses, geological heterogeneity is represented by preferential channels embedded in a more homogeneous matrix, representing alluvial aquifers, and by stratified systems with oriented structures, similar to those found in fractured media.

Effective tools applied to upscale the behavior of the observed plumes in all configurations and independent from the assumption of ergodicity and stationarity agree in that connectivity, mixing and stratification are common aspects controlling the temporal scaling of solutes arriving at the pumping wells.

Identifying these mechanisms and explicitly embedding them in upscaled models contribute to a more comprehensive and accurate use of effective models for predictive purpose of solute plumes in complex aquifer configurations.

Code of abstract: T3.4.3
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Reactive transport modeling for the evaluation of field scale substrate competition in a complex contaminated site

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KEY WORDS reactive transport modeling, redox processes, reductive dichlorination, substrate competition, coastal aquifer

ABSTRACT
Within a plume, the redox processes are the main drivers of pollutants' behavior and fate. In fact, when fuel-derived organic compounds, such as BTEX and MTBE, are released in groundwater, they degrade by fermentation or direct mineralization. The oxidation of the fermentation by-products, such as H_2 and Acetate, and/or of the primary substrate (electron donors) obviously triggers the reduction of redox-sensitive compounds (electron acceptors) naturally present and/or anthropogenically released in the aquifer, a phenomenon well known as Terminal Electron Accepting Process (TEAP). The TEAP is catalyzed by different microbial species, each one using the available substrate and the corresponding electron acceptor. Thus, if in the same polluted site, in addition to endogenous electron acceptors (i.e. Nitrate, Mn(III/IV) hydr-oxides, Fe(III) hydr-oxides, Sulfate, etc.), chlorinated ethenes (i.e. PCE, TCE, DCEs, VC) are present, reductive dichlorination processes could likely be inhibited, because of the competition among the corresponding microbial species.
In order to get a deeper insight into this issue, the modeling of reactive transport has been applied, simulating the degradation processes and interaction among several compounds along the main flow path (1-D model) in a coastal area, where a silty sandy aquifer, 10-15 meters thick, overlays a clayey aquiclude. Here, several foundry wastes burials (with an high content of Mn and As-rich Fe hydr-oxides), an oil spill from fuel station tanks and a chlorinated solvents residual phase have been revealed.
For kinetically controlled processes (i.e. fuel-derived organic compounds degradation and reductive dechlorination), different equations have been used and compared: the first-order equation, the Michaelis-Menten equation, and the Monod equation. The simulation has been performed with Phreeqc and the results validated using chemical analyses made on groundwater samples collected in a 43 well monitoring network.
The first results show a persistence of reductive dechlorination of by-products (i.e. DCEs and VC) in groundwater, near the largest foundry wastes burial. In fact, the correspondence between the high concentration of DCEs and VC and the high concentration of Mn, Fe and As in groundwater suggests a strong competition for the substrate.

Code of abstract: T3.4.4
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Specifics of contaminant plume migration from the tailing pond within multilayer Quaternary aquifer with important influence of the river hyporheic zone

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KEY WORDS plume migration, numerical modeling, hyporheic zone, tailing pond, site specific conditions,

ABSTRACT

A contaminant plume of high concentrations of chlorides migrates from the former tailing pond located in the South-West Poland what pose a risk for aquatic system, as the pollutants migrates downstream (to South, South-West) in the direction of the local rivers. The mining waste deposition at the tailing pond created an overpressure and polluted waters were press down into the deeper parts of the Quaternary aquifer consist of sands with a lot of clay lenses located at different depths. Inflow of the contaminant plume into the draining river differs from the theoretical idealized scheme, with confirmed occurrence of pollutants on the other side of the river.
To represent the complexity of the site conditions and describe the plume migration under significant influence of groundwater – surface water interactions (in hyporheic zone), a numerical model (up to 85 km^2) was created. The model confirmed that chlorides first migrates from the source (former tailing pond) down into the aquifer and then downstream to the river. However, the river does not form a barrier for the plume as the results showed that the plume migrates further under the river in deeper parts of aquifer. It indicates that the water exchange in hyporheic zone between groundwater and surface waters occurs only in upper level of the aquifer. Pollutants migration observed in a deeper level of the aquifer are stopped by the groundwater flux from the other side of the river and then contaminant plume moves into the river along complex ascending pathlines in relation to clay lenses location. Interesting is also that contaminant plume migrates in the hyporheic zone parallel to the river and is captured (drained) by the river with some delay or difficulty.
Presented case points to the significant perception between the idealized results of numerical modeling and the real flow conditions of groundwater. The only solution for this type of case is intensification of the monitoring studies in the immediate vicinity of surface waterways (in both sides), with particular emphasis on the hyporheic zone.

Code of abstract: T3.4.5
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Applying modelling results to a modified query: the regression of chloride on modelled TDS

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KEY WORDS salinity, feflow, groundwater modelling, regression, chloride, TDS

ABSTRACT
For a study area with naturally occurring, extensive salinity variations of formation waters, a numerical groundwater model was set up to simulate regional flow patterns and solute transport. The task was challenging due to the following facts: 1) The 3D modelling space is large, covering an area of 1220km^2 with a maximum depth of 1000m to give a holistic picture of the total groundwater flow behaviour in the region. 2) Salinity was highly variable in the region: On the one hand, it generally increased with increasing depth, but was also spatially not uniformly distributed. On the other hand, its composition, i.e. the total dissolved concentration of major inorganic ions (Na, Ca, Mg, K, HCO_3, SO_4 and Cl), differed spatially. Simulation of density dependent flow was therefore carried out for TDS and was numerically challenging due to highly dense waters in combination with strong gradients. 3) Simulations were carried out for a considerably long time span of 90 years for past and current conditions, complemented by additional 45 years of scenario simulation time. Four years in the project, the pressing question moved from regionally simulating flow patterns of TDS to the simulation of local Chloride concentrations at and around drinking water wells. Even with a calibrated model, this (new) question was not easy to answer due to the spatial variability of the salinity composition. This contribution will discuss obstacles and challenges involved in the modelling process itself, i.e. model set-up and calibration, and furthermore present a method to regress chloride on TDS. Modelling was carried out with the three-dimensional density-coupled flow and mass-transport simulation system FEFLOW®.

Code of abstract: T3.4.6
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Statistical methods and stochastic modeling to assess groundwater PCE diffuse pollution in Milan Functional Urban Area -

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KEY WORDS - diffuse contamination, statistical multivariate, cluster analysis, transport modeling, MODFLOW

ABSTRACT
In recent years, the new National and Regional regulations consider the necessity to develop plans for the remediation and management of the most industrialized areas, affected by groundwater contamination due to both Point Sources (PS, associated with medium/large dimension sources, i.e. hot-spots) and Multiple Point Sources (MPS, constituted by a series of unidentifiable small sources clustered in a large area, that cause a diffuse anthropogenic contamination). Nor the National legislation nor the contents of the Regional plans provide methodologies to quantify the phenomenon and to distinguish the PS and MPS in urban areas.
The latter category predominates in European Functional Urban Areas (FUA) and cannot be managed with remediation techniques such as those commonly used for large/medium contaminated sites, mainly because of the difficulty to identify the many different source areas that release or that released in the past contaminant mass. Consequently, the usual remediation procedures are not economically sustainable. Due to the European relevance of the topic, the EU project AMIIGA (CE32, Interreg Central 2016-19) aims to set up a groundwater management plan that involves also the evaluation of MPS diffuse groundwater contamination in European FUAs.
This work presents the results of the study about tetrachloroethylene diffuse pollution in the FUA of Milan and supply a contribution to the identification of PS and MPS contaminations. By combining statistical analysis of monitoring data, deterministic mathematical modeling to simulate the shape of PS plumes and stochastic modeling of MPS it is possible to

- Distinguish among PS (hotspot) and MPS (diffuse) contaminations in urban groundwater
- Assess the plume extension generated by PS and their influence on quality status of downgradient areas
- Estimate the diffuse contamination level with reference to the Italian Law threshold limit (1.1 ug/l), considering dominant cluster summary statistics (Approach 1) or the summary statistic mean related to cluster frequency (Approach 2)
- Prepare a ranking list of the areas that most probably host MPS responsible of the PCE diffuse contamination

Code of abstract: T3.4.7
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Experimental and numerical study of pollutant migration process in an aquifer in relation to Shaziying garbage dump field

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KEY WORDS：Pollution process, Shallow aquifer, Garbage dump field

ABSTRACT

The water quality of shallow aquifers that have direct relationship to human health and ecological safety has been seriously threatened by widespread dumping of industrial solid waste, urban and rural garbage. A garbage dump field with hydrogeological, environ-geological characteristics typical of the Beijing plain was selected for investigation. A hydrogeological model was constructed and the equations used to describe pollutant transport in one-dimensional (1D) steady, uniform groundwater flow to investigate the transport/diffusion processes. In addition to the coefficients for calculation, diffusion coefficient and other coefficients of the aquifer were obtained by conducting in situ diffusion experiments and sample tests. Velocity and scope of pollutant transport/diffusion process were calculated. Accordingly, the real pollution situation in the aquifer was evaluated through in situ drilling and sample testing. Transport/diffusion processes of pollutants within the aquifer abide by the solute equation applicable to one-dimensional steady flow. The transport and diffusion dominate in the direction of groundwater flowing at a speed of about 86.25 meters per year. Comparably, the lateral diffusive width is much smaller, only one seventeenth of that.

Code of abstract: T3.4.8
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Comparison of numerical model, neural intelligent and geostatistical in estimating groundwater table

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KEY WORDS - Numerical Model, CANFIS, Wavelet-ANN, geostatistical, Groundwater Table

ABSTRACT
Predicting groundwater levels are difficult and time consuming due its nonlinearity and complexity. Models provide groundwater managers and decision makers an efficient and low cost tool. The purpose of this study was to compare the numerical model, neural intelligent and geostatistical method to predict the groundwater table changes. The Hamedan – Bahar aquifer as one of the most important water sources in Hamedan province, Irna was studied. In this study, MODFLOW numerical code in GMS software, artificial neural network (ANN) and neural – fuzzy (CANFIS) method in NeuroSolution software, wavelet- neural method in MATLAB and geostatistical method in ArcGIS software were used. The results showed that the accuracy of methods in estimation of the groundwater table with the lowest Normal Root Mean Square Error (NRMSE) include Wavelet-ANN, CANFIS, geostatistical, ANN and numerical model, respectively. The NRMSE value in Wavelet-ANN method as optimization method was 0.11 % and in numerical model was 2.2 %. In addition, the correlation coefficients were 0.998 and 0.904, respectively. So, application of neural combination models, wavelet theory, in the estimation of groundwater table was the most suitable method compare to geostatistical and numerical model for selected aquifer.

Code of abstract: T3.4.9
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Determination of bacterial sorption type during the transport in the areal two-dimensional sandy aquifer

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KEY WORDS bacterial sorption model, two-dimensional transport, bimodal shape, reactive solute transport

ABSTRACT
Transport of the microorganisms in the saturated porous media has been widely studied because of the importance of the behavior of pathogenic microorganisms and the microbial degradation of organic contaminants in the contaminated aquifers. For the better prediction of the bacterial transport in the aquifer, we investigated bacterial sorption and transport by conducting transport experiment in the areal two-dimensional sandy aquifer model in which the bacterial plume is closer to the actual migration than the breakthrough curve obtained in the one dimensional aquifer model. At the steady state, the tracer is injected instantaneously, and the pore water was sampled at the sampling points located in the lattice to observe the two-dimensional distribution of the solute. The bacterial plume showed retarded transport than the conservative tracer (KCl). The result of the moment analysis showed the mass attenuation at 24h, which might be due to the bacterial sorption on sand surface. And the bacterial plume showed elongated distribution along the flow path and bimodal distribution, in which the advancing peak is much higher.
Numerical modeling of 2D bacterial transport was conducted using advection-dispersion equation in conjunction with various types of sorption to determine the appropriate model for the description of bacterial sorption during the transport. The sorption models were constructed by combination of equilibrium, kinetic-reversible, kinetic-irreversible types of sorption models. Among the single type sorption models, the kinetic-reversible sorption model could simulate all the retardation, mass reduction, and bimodal distribution. The complex sorption models including kinetic reversible sorption could enhance the goodness of fit significantly than that of the single type sorption models. This indicates the sorption processes during the transport in the two-dimensional aquifer material are complex so that it is necessary to consider the complex types of sorption process especially including the kinetic reversible sorption.

Code of abstract: T3.4.10
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Effect of hydraulic aperture distributions on block hydraulic properties of the 2-D discrete fracture network system

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KEY WORDS hydraulic aperture, discrete fracture network, block hydraulic properties, numerical experiments, equivalent continuum behavior

ABSTRACT

Fracture geometry parameters such as orientation, density, length and aperture play an important role in the block hydraulic properties of fractured rock masses. In this study, the two dimensional steady-state fluid flow through discrete fractured geologic media is addressed to examine the effect of aperture distribution of individual fractures on the block hydraulic properties of fractured rock masses based on numerical experiments. A total of 216 stochastic 2-D DFN (discrete fracture network) blocks were generated using two fracture sets with fixed input fracture geometry parameters of uniformly distributed orientation and density, and gamma distributed trace length. Two different cases of fracture aperture variation are considered for prepared 2-D DFN blocks. One case deals with the DFN blocks with different ratios of fracture hydraulic aperture for fracture sets, and the other is case of lognormally distributed hydraulic aperture within fracture set. The block hydraulic properties such as directional block hydraulic conductivity, theoretical block hydraulic conductivity, principal hydraulic conductivity tensor and average block hydraulic conductivity were estimated for prepared 216 2-D DFN blocks. The results obtained from this study show that the average block hydraulic conductivity of the DFN block increases as the hydraulic aperture of one fracture set increases relative to the hydraulic aperture of another fracture set. This is probably due to the increase of the block hydraulic conductivity in the direction of the fracture set with wider hydraulic aperture. The differences in hydraulic aperture between fracture sets can have a significant effect on the anisotropic block hydraulic conductivity and the chance for equivalent continuum behavior of the DFN system. This implies that the domain of fluid flow modeling should be set to a size larger than the representative element volume when equivalent continuum approach is applied to tackle the field problems. In case of lognormally distributed hydraulic aperture within fracture set, the hydraulic anisotropy increases as the standard deviation of the hydraulic aperture increases, and the chance for equivalent continuum behavior of the DFN system decreases. This is probably because a small number of fractures having extreme values of hydraulic aperture may have a significant influence on the hydraulic behaviors of the overall system.

Code of abstract: T3.4.11
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Groundwater flow and mass transport regimes around a fault from numerical simulation and environmental tracer analyses

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KEY WORDS mass transport, fault, tritium, sulfur hexafluoride, dichlorodifluoromethane

ABSTRACT

The impact of faults on fluid flow and mass transport is important in many processes, such as contaminant migration, oil and gas migration, and hydrothermal deposit formation. In this study, groundwater flow and mass transport analyses of chloride ions, tritium, sulfur hexafluoride (SF_6), and dichlorodifluoromethane (CFC-12) were conducted to determine groundwater flow and mass transport regimes around a fault. Estimated spatial and temporal distribution of the concentrations were compared with measured values.

The modeled region is in Mizunami, Gifu prefecture, Japan. The vertical Main-Shaft Fault cross-cuts sedimentary formations and granite basement. This fault is exposed along the Main Shaft of the Mizunami Underground Research Laboratory operated by the Japan Atomic Energy Agency. A hydrogeological model of the region surrounding the fault was developed and the fault was modeled as a low-permeability fault core between high-permeability damage zones. MODFLOW by USGS and MT3DMS by Zheng and Wang (1999) were used for the simulations. A known concentration gradient with depth and a recharge of water with zero concentration were assumed in the calculation of chloride ions. Temporal changes in tritium, SF_6 and CFC-12 concentrations in recharge water were considered, in addition to drainage from one point in the fault core and one on the southwest side of the fault. Groundwater samples were collected from boreholes in the galleries to determine the concentrations of the dissolved ion and environmental tracers.

The simulations revealed higher heads on the northeast side of the fault than on the southwest side. Groundwater flow toward the drainage points was clearly observed on the southwest side but the effect of drainage points was limited on the northeast side. The mass transport analysis showed variations of chloride ion concentration mainly in the damage zones and it was more apparent on the southwest side. Tritium, SF_6, and CFC-12 concentrations were elevated by the infiltration of surficial groundwater along the damage zones on both sides of the fault, but the surficial water penetrated deeper on the southwest side. These results were consistent with groundwater flow and mass transport regimes interpreted from measured values.

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Code of abstract: T3.4.12
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

HYDROGEOLOGICAL CARACTERIZATION AND NUMERICAL SIMULATION OF THE PYROCHLORE DEPOSIT, ASSOCIATED TO BARREIRO ALCALINE CARBONATITIC COMPLEX, ARAXÁ - BRAZIL

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KEY WORDS - Hydrogeological modelling, Barreiro Alcaline Carbonatitic Complex, Finite Elements, Visual ModFlow.

ABSTRACT

The interferences in availability and water quality of a hydraulic system, caused by mining activities, must be analyzed by mining companies, in order to continue the long-term projects. The intersection between ore explotation and groundwater level, often becomes a problem to mining operations, due to the high ore humidity, which can even influence the mineral processing. The pyrochlore deposit, which is the subject of this study, has been operated by the Companhia Brasileira de Metalurgia e Mineração (CBMM), concentrating the niobium ore since the 1970s. In the last five years, due to the pit depth, it was necessary to characterize the deposit from hydrogeological point of view. Since the planned pit surfaces for long-term presented interferences with the groundwater level, which strongly makes the project unfeasible, the aim of this research is to perform a hydrogeological characterization study of the aquifer associated with the niobium field, planning to generate data for numerical modeling of groundwater flow. The analysis of hydrodynamic, hydrochemical and isotope data shows that the main aquifer of the study area is related to the weathering cover of the carbonatite rock, which is the niobium ore. The aquifer have hydraulic conductivities ranging from 10^{-6} m/s to 10^{-5} m/s, being capped by less permeable soils (8.7 x 10^{-7} m / s), which work as aquitards, making the aquifers semi-confined, locally. In the southeast portion of the study area there is an important underground flow divider and the main flow direction observed is from southeast to northwest, with discharge in the vicinities of Barreiro's Resort. The numerical modeling calibration had good levels of accuracy and satisfactory approximation with the proposed conceptual model. The numerical model, calibrated on steady-state will be used for many simulations in groundwater management activities.

Code of abstract: T3.4.13
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Identification of mathematical model and parameter estimation of Erythromycin migration in two different porous media based on column tests

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KEY WORDS groundwater, erythromycin, sorption, optimization

ABSTRACT
The amount of pharmaceuticals found in groundwater has risen over the last few years. Erythromycin is an example of an antibiotic widely used in human health care and veterinary practice that can be transported into the subsurface. The aim of the presented research was to 1) determine the mathematical model of erythromycin migration in two different porous media, 2) estimate the model parameters and 3) compare the migration of the antibiotic in the investigated media. The research was conducted in a specially prepared laboratory workplace where column test was performed. One column was filled with glass granules (70% SiO_2, 600 – 800 μm in diameter) and a second column was filled with a natural sediment (sandur sand). The migration of a conservative tracer and erythromycin was examined in both columns. Experiments were performed in two separate steps. In the first step, a conservative tracer, subject to advection and dispersion processes, was injected into the column and its transport was investigated. The second step involved investigating the migration of erythromycin. A conductivity meter was installed at the output of the column in order to determine tracer concentrations based on calibration curves. Short-time pulse injections were applied during the experiments. The interpretation of experimental results was conducted in the MATLAB environment. The mathematical model of erythromycin migration was determined from the shape of pulse breakthrough curves, which were characterized by a set of descriptors: the time of maximum tracer concentration at the output t_{max}, the spread of the breakthrough curve σ, relative tracer recovery ε. This procedure involved implementing an identification algorithm developed by the authors. It was proved that the migration of erythromycin is best described by a hybrid model that assumes the coexistence of equilibrium and non-equilibrium sorption. In the next stage of research, the transport and sorption parameters were estimated through numerical optimization procedures. The convergence between theoretical and experimental breakthrough curves was analyzed qualitatively by calculating the *RMSE* and the correlation coefficient *r*.

The research described here was funded by the Polish National Science Centre (grant no. DEC-2011/01/B/ST10/02063).

Code of abstract: T3.4.14
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Modelling impact of changing in agricultural land use on the nitrogen outflow from middle size catchment in S Poland

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KEY WORDS nitrogen, modelling, Nless, Visual Modflow

ABSTRACT

Mathematical hydrodynamic models have an undying popularity both in the context of the quantitative assessment and predictions of contaminants migration. A properly designed hydrodynamic model can also be a useful tool for designing of monitoring networks. The authors present the application. The aim of the study was to compare the effects of different land use options to the outflow of nitrogen from agricultural catchment with complicated hydrogeology conditions. Flow in the Kocinka river catchment is strongly depending on inflow from karstic aquifer (Jurassic Major Groundwater Basin MGWB326). For this situation hydrological models not included sufficiently detailed groundwater flow not give realistic resultants.

Methodology used by authors combines two aspects - leaching of nitrogen and flow of surface waters and groundwater in catchment area. Modelling of ground flow and transport was made using hydrogeological model Visual Modflow. Leaching from roots zones was calculated by model N-LES4. Pattern of the soils and crops types was supplemented with information of agricultural practices, fertilization levels and soil properties. Observations of river outflow, chemical and isotopic properties of groundwater and surface water was made in 2014-2016. Model Nless4 allowed to reflect the actual conditions of arable area and make calculation for land use changes scenarios. Comparison of the results with each other 4 scenarios: A business as usual B. Agriculture profit C. Sustainable agriculture D. Ecological agriculture. Results from NLess4 are spatially oriented using ArcGIS desktop and implemented to hydrogeological model Visual Modflow. Model for case study area was previously calibrated using hydrogeological data and tritium. It takes into account the flow rate of nitrogen in the groundwater, which is delaying by lag time effect.

Acknowledgements

The work was supported by BONUS-Soils2Sea project (http:/www.soils2sea.eu) financed by the European Commission 7 FP contract 226536 and the statutory funds of the AGH University of Science and Technology (project No.11.11.140.026 and 11.11.220.01).

Code of abstract: T3.4.15
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

NUMERICAL SIMULATION OF ORGANIC CONTAMINANTS SPILLS ON THE VADOSE ZONE USING A SIMPLE ONE-DIMENSIONAL FINITE DIFFERENCES MODEL

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ABSTRACT

The impact of fuel spills in the soil (as those coming from Underground Storage Tanks – UST) is performed using a one-dimensional mathematical model of fate and transport of BTEX in the vadose zone. The model uses the Millington Equation, a theoretical approximation for gaseous diffusion in porous media which has been widely used in the fields of soil physics and hydrology to calculate the gaseous or vapor diffusion in porous media.

The movement of organic contaminants within and between three different phases is described: (1) as a solute dissolved in water, (2) as a gas in the vapor phase, and (3) as an absorbed compound in the soil phase. Initially, the equilibrium distribution of contaminant mass between liquid, gas and sorbed phases is calculated. Transport processes are then simulated. Liquid advective transport is calculated based on values defined by the user for infiltration and soil water content. The contaminant in the vapor phase migrates into or out of adjacent cells based on the calculated concentration gradients that exist between adjacent cells. After the mass is exchanged between the cells, the total mass in each cell is recalculated and re-equilibrated between the different phases. At the end of the simulation, (1) an overall area-weighted groundwater impact for the entire modeled area and (2) the concentration profile of BTEX on the vadose zone are calculated.

Code of abstract: T3.4.16
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Numerical Simulation of Regional Groundwater Flow in a Data-poor Region, China

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KEY WORDS - nuclear waste disposal; the Beishan area; TOUGH2; groundwater flow; unsaturated zone

ABSTRACT

The use of nuclear energy will probably produce a number of high-level radioactive wastes (HLRW), which brings potential environmental danger. Selecting a proper disposal repository is a crucial step to develop the nuclear energy. In China, the research on HLRW is relatively late. The Beishan area is selected as the most prospective site for disposal repository of HLRW in 1989. The area of the Beishan region is approximately 70,000 km^2, however, there is limited data about groundwater system, and it is necessary to develop a saturated-unsaturated groundwater model to assist site selection of HLRW in the data-poor region. Also, the influences of climate change or faults on regional groundwater flow need to be further addressed. This paper introduces hydrogeology conditions of the Beishan area. Then a regional groundwater flow model in the Beishan area is constructed using TOUGH2-MP/EOS3 to analyze the groundwater flow pattern. The model calibration shows the simulated and observed hydraulic heads match well, and the simulated regional groundwater flow pattern is similar to flood flow pattern from the river network generated by Arc Hydro Tools, indicating groundwater flow is mainly depended on the topography. In addition, the simulated groundwater and soil water storage variations have a slight decreasing trend (-0.193 cm/a) over the period from 2003 to 2014, which is similar as the trend (-0.224 cm/a) derived from derived results of the Gravity Recovery and Climate Experiment (GRACE) satellite. Results find that there is only about 0.01% precipitation infiltrating into groundwater. At last, the established model is used to evaluate the influences of the extreme climate and regional faults on groundwater flow pattern in the study area. Results show that they have not a significant influence on regional groundwater flow patterns. This study will provide a preliminary reference on the regional groundwater flow in the Beishan area, which will be helpful for the site selection of HLRW in China.

Code of abstract: T3.4.17
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Role of fluid driving forces in large sedimentary basins — case study from the Pannonian Basin, Hungary

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KEY WORDS sedimentary basins, numerical modelling, overpressure, gravity driven flow system

ABSTRACT
In large sedimentary basins groundwater is usually driven by numerous driving forces, resulting in complex groundwater flow systems. Beside the most frequent impelling force, the gravity, overpressure caused by compression and compaction, underpressure, as well as variable density can have an important effect. In large basins various effect can be present next to each other. Numerical modelling is a perfect tool to recognize and distinguish between the different driving effects. In addition to that, the geological history of the area is a key factor in understanding the pressure, temperature and chemical conditions, which also influence the formation and distribution of flow systems. The Great Hungarian Plain, Hungary is a perfect study area to examine the complexity of flow regimes governed by different driving forces. Based on the geological history of the area and applying the groundwater flow system concept, detailed numerical modelling study was carried out to identify the role of the main driving forces on the groundwater flow regimes. Data based hydraulic analysis has already showed the presence of shallow, hydrostatic and deep overpressured regimes, but – having favorable geothermal conditions – the effect of temperature cannot be excluded. The detailed modelling study proved, that not only gravity, but compression/compaction, and density also influence the present flow paths.

Code of abstract: T3.4.18
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.4. Groundwater flow and transport modelling

Using a combined classic hydrogeological, hydrochemical and isotopic approach for a conceptual groundwater flow model development in southern Benin.

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KEYWORDS: Conceptual models, Hydrochemistry, isotopes, Piezometry

ABSTRACT
The sustainable development of groundwater resources is critical to future safe water supply. This depends on a good understanding of groundwater and hydrogeology. Groundwater flow and transport modeling is well recognized as a powerful approach to understanding and accessing hydrogeological systems with respect to various stresses. However, the conceptual models upon which the hydrogeological models are developed suffer usually from data scarcity. Accordingly, developed hydrogeological models may be inaccurate to some extent. The objective of this study is to use a combined classic hydrogeological, hydrochemical and isotopic approach to develop a coherent groundwater flow conceptual model and access if hydrochemistry could be useful to develop a conceptual groundwater flow model under groundwater head data scarcity. We use as a case study the Turonian-Coniacian aquifer in southern Benin.
The methodology could be divided into two steps. First, groundwater level was measured in existing wells across the area of research to draw piezometric maps. Second, groundwater samples were collected for chemical and isotopic (stable isotopes and tritium) analysis.
Results from the piezometric survey show three main groundwater flow directions in the Turonian-Coniacian aquifer. In the western research area, a main Northwest to Southeast flow direction is noted. In the central, a North to South flow direction is noted. In the Eastern research area, a Northeast to Southwest flow direction is noted. Stable isotopes results confirm the piezometry as the most depleted and more enriched values in Oxygen-18 and deuterium are found respectively in the discharge and recharge areas indicated by the piezometry. Similarly, higher tritium values (above 01 Tritium Unit) and low tritium values characterise recharge and discharge areas respectively, hence confirming the piezometry. However, the groundwater mineralization as measured through the Total Disolved Solids seems not to follow the piezometry, hence may not be a good candidate in developing a conceptual groundwater flow model under groundwater head data scarcity.
This study has helped developed a coherent groundwater flow conceptual model and is an example of research that should precede hydrogeological modeling exercises.

Code of abstract: T3.5.1
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Groundwater processes in geomechanical models of underground mining

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KEY WORDS hydro-geomechanical models, pore pressure, subsidence

ABSTRACT

Geomechanical models of underground mining are developed primarily to determine change in stresses and surface subsidence, and could also include groundwater processes. Geomechanical models should explicitly include hydrological interactions because increasing saturation reduces rock strength, and also because reduced pore pressure of saturated rock increases effective stress. Groundwater models, in contrast to geomechanical models, are designed to model relatively large areas of groundwater drawdown, but generally do not directly model the effects of rock deformation. This research overviews the capabilities and limitations of common geomechanical model codes with regard to saturation, pore pressures and groundwater flow (eg. UDEC, FLAC, PHASE2).

Two examples of 2D cross-sectional models with coupled hydro-geomechanical capabilities (run in 2D steady state) will be provided for generic underground excavations in a ~300 m depth coal seam of the Sydney Basin. In the first case, a model was developed in the finite difference FLAC code with the aim of evaluating the influence of geological heterogeneity on deformation of overburden strata and groundwater flow. The model domain was 1600 m long and 550 m thick, with uniform element sizes 4 m by 2 m. This continuum model simulated the extraction of a longwall panel by matching an empirical incremental profile of subsidence. In the second case, the PHASE2 code simulated conditions that contribute to stress-corrosion failure of roof supports in underground mines. The model domain (15 m width by 15 m thick, with ~11,0000 elements of variable size) included a 2 m steel bolt grouted in the roof of an excavated roadway surrounded by various layer combinations of coal, clay, sandstone, and shale. The model was based on generic material properties, hydraulic conductivity and joint properties, and the results compared with groundwater drip rates from bolts in the mine roof.

The relative capabilities of models to include geological heterogeneity, semi-saturated processes, matrix flow, fracture flow, bedding separation and the influence of geological faults is considered. We recommend that evaluations of groundwater and subsidence include realistic hydrological influences depending on site specific processes and the purpose of the model.

Code of abstract: T3.5.2
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Groundwater resources dynamics in small-scale river basin under climate change conditions

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KEY WORDS groundwater resources, calibration, simulation, recharge and evapotranspiration

ABSTRACT

Detecting the influence of the observed long-term variability of temperature and precipitation during latter half of the 20th and the early 21th centuries on changes in groundwater levels and discharge in the Sudogda River basin (Russian Federation) by numerical modeling is the purpose of this investigation. The scientific and social relevancy is determined by estimation of the possible climate variations in 21th centuries on water resources.
First of all, the Sudogda River basin was typing due to the landscape and to the unsaturated zone texture classes. For each zone using unsaturated zone flow simulation it was calculated average annual recharge and besides this the annual dynamic of recharge during whole observation period.
On the next step the calibration of regional flow model was conducted using data of regional monitoring network and conceptualization of hydraulic heterogeneity by mapping of large planar zones. The calibration was made for steady-state and transient model. The main parameters of interest were aquifer hydraulic conductivity and recharge rate. It is impossible to evaluate them both using just one parameter set. Those parameters are highly correlated. To deal with that problem the calibration with joint objective function that includes weighted hydraulic head and weighted streamflow observations was used to improve model fit. Weights of each observation were calculated according to observation error and modified to reflect observation count. Majority of head observations were assigned with lower weights so heads and streamflow rate observation groups had comparable sensitivity. After sensitivity analysis the weights of observation consistent were further adjusted for same purpose – to equalize their contribution to objective function.
Three observation sets, when heads and streamflow rates were measured, were used to calibrate a model. In those years annual amount of precipitation and groundwater abstraction was different. Additionally, multi-year precipitation records were analyzed to detect any long-term recharge changes. Estimated recharge rates in mentioned years showed good correlation with precipitation changes. Hydraulic conductivities evaluated using said three observation sets are consistent.
These investigations were supported by the RSF No. 16-17-10187

Code of abstract: T3.5.3
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Multipurpose project Programme Sava – numerical modeling of impact of Option 2A conceptual solution on groundwater

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KEY WORDS Programme Sava, Option 2A, numerical modeling, groundwater

ABSTRACT

Identification of impact of Option 2A conceptual solution of the multipurpose project Programme Sava (http://zagrebnasavi.hr/sava-zagreb/) on groundwater of the Zagreb and Samobor-Zaprešić aquifers, Croatia, is presented and the results are discusses with respect to the results of previously analysed conceptual solutions of Options 0, 1 and 2. Option 0 represents technical solution that would achieve the defence from flooding and regulation of the Sava River and considers construction of sixteen control weirs in the Sava River. Option 1 is considering the construction of four hydropower plants, HPP Drenje, HPP Zagreb, HPP Prečko and HPP Podsused along with the channel Sava – Sava while Option 2 considers the construction of two hydropower plants, HPP Prečko and HPP Zaprešić as well as four small hydropower plants (SHPP), SHPP Jarun, SHPP Šanci, SHPP Petruševec and SHPP Ivanja Reka and envisages the channel Sava – Sava, same as Option 1. Alternative conceptual solution named Option 2A considers construction of 9 small hydropower plants in the Sava river and also envisages the channel Sava – Sava, same as Options 1 and 2. Regional groundwater flow model for present state as well as prediction models for built environment were developed in order to identify impact of built environment on groundwater levels of Zagreb and Samobor-Zaprešić aquifers as well as active well fields. Beside regional groundwater flow models, 2D cross-section numerical models were developed for Options 1 and 2 in order to assess seepage from HPP pools into the drainage systems and hinterland and to acquire outer boundary conditions for regional groundwater flow models.

Code of abstract: T3.5.4
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

MOFLOW-based web modeling framework

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KEY WORDS MODFLOW, numerical modeling, web-based, cloud modeling, managed aquifer recharge

ABSTRACT
The INOWAS-DSS platform provides a collection of free web-based tools for planning, optimization and management of main components of managed aquifer recharge (MAR) schemes. All tools are running on a web server which controls the processing on a number of clustered computers and allows accessibility via standard web browsers. In this way, the INOWAS-DSS can combine GIS-functionality and a user-friendly GUI with process-based high-performance computing.
The simulation core of the INOWAS-DSS is based on the numerical groundwater flow model MODFLOW-2005 (Harbaugh, 2005) and FloPy (Bakker et al. 2016). The platform provides the user with the option to set up and calculate a new groundwater flow model including grid generation, layer creation, and implementation of relevant boundary conditions. After calibration of a base case scenario, various scenarios can be added where boundary conditions can be easily varied to evaluate new management options as well as future development in the study area. A specific tool called “Scenario Analyzer” helps the user to compare and analyze the simulation results. Different analysis options such as cross sections of groundwater levels or drawdowns, time series analysis, volumetric budget evaluation, and the calculation of head differences between different scenarios help to identify best management options.
A case study of a groundwater flow model of the city centre in Hanoi, Vietnam is presented showing the features and applicability of the web-based modeling platform for the sustainable management of groundwater resources and especially the restoration of local groundwater levels with the help of MAR.
The INOWAS-DSS comprises a new framework, which is easily accessible via standard web browsers, provides best accessibility of project data and multi-institutional collaboration through web-based implementation; and makes use of a combination of widely available open-source tools.

Code of abstract: T3.5.5
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Using advanced modeling tools for sound groundwater governance of transboundary aquifers in southern Africa: the Stampriet Transboundary Aquifer System case study

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KEY WORDS Stampriet Transboundary Aquifer System, participatory approach, H2020 FREEWAT, GGRETA project

ABSTRACT

The Stampriet Transboundary Aquifer System (STAS) area extends over about 87000 km², from Central Namibia into Western Botswana and South Africa's Northern Cape Province. Due to the lack of permanent surface water, human activities (mostly related to agriculture) only rely on groundwater and the STAS is particularly vulnerable to overexploitation and pollution. Furthermore, the lack of a proper monitoring network seriously hampers a systematic analysis of the stresses involved.

Within the framework of the "Governance of Groundwater Resources in Transboundary Aquifers" (GGRETA) project, funded by the Swiss Agency for Development and Cooperation (SADC), the Governments of Botswana, Namibia and South Africa, jointly with the UNESCO International Hydrological Programme (UNESCO-IHP), are undertaking an assessment of the quantitative and qualitative status of the STAS. The major scope of the GGRETA project is to support the establishment of a Multi-Country Cooperation Mechanism, the first one in Southern Africa, for management and governance of the STAS.

The outcomes of the GGRETA project consist in tables, thematic maps and databases of relevant data from different regional and national sources. Such results were integrated with previous modeling applications to support the implementation of a hydrogeological numerical model, in the framework of the H2020 FREEWAT project (FREE and open source software tools for WATer resource management, www.freewat.eu; Rossetto et al., 2015). The model is being developed through the application of the FREEWAT platform, a free and open source, GIS-integrated modelling environment which integrates spatially distributed and physically based codes for the simulation of the hydrologic cycle aiming at facilitating water planning and management.

FREEWAT applicability is demonstrated by running 14 case studies and enhancing participatory approach to involve relevant stakeholders in the evidence-based decision making process for water resource management. Among the 14 case studies, the STAS is particularly representative, as it aims at facilitating the link between science based analysis and stakeholder participation for the adoption of sound transboundary management policies. This is done by combining a series of capacity building (e.g., training the trainers) and water diplomacy (e.g., focus groups) modules aimed at ensuring sustainability and regular update of the STAS model.

Stakeholders involved for the STAS case study belong to governative agencies, research institutions and parastate water companies of the three Countries involved. They demonstrated a positive perception about the use of advanced modeling tools for sustainable management of transboundary aquifers, in order to: (i) assess the status of the STAS under different scenarios of exploitation; (ii) evaluate the importance and feasibility of Managed Aquifer Recharge solutions; (iii) identify the areas were more data are needed; (iv) set the stage for a groundwater management plan shared among the three Countries; (v) set up a strategy to be adopted and extended to other transboundary aquifers.

Acknowledgements

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References

Rossetto, R., Borsi, I., Foglia, L. (2015) - FREEWAT: FREE and open source software tools for WATer resource management, Rend. Online Soc. Geol. It., Vol. 35, pp. 252-255, doi: 10.3301/ROL.2015.113

UNESCO-IHP (2016) – Stampriet, Transboundary Aquifer System Assessment – Governance of Groundwater Resources in Transboundary Aquifers (GGRETA), Phase 1 – Technical Report, 168 pp.

Code of abstract: T3.5.6
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Water quality prediction mapping with the Groundwater Assessment Platform (GAP)

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KEY WORDS - groundwater quality, GIS, prediction mapping, geospatial modeling

ABSTRACT
Roughly one-third of the world's population relies on groundwater for drinking. To help monitor and assess the water quality of this limited resource, the Groundwater Assessment Platform (GAP) was developed as a free online GIS tool for the analysis and modelling of groundwater quality data (*www.gapmaps.org*). GAP enables users to upload their own point, shape or raster data and share these with other users or groups of users. These data can then be used in logistic regression modeling to create a hazard prediction map of the water quality parameter in question. The advantage of this technique to interpolation mapping is that logistic regression produces a model based on statistical relationships with predictor variables that may be proxies for the mechanisms causing the presence of the modeled concentrations. Various publicly available environmental data that are potentially relevant as predictor variables, such as geology, soil and climate parameters, have been pre-loaded in GAP for use in modeling. We show examples of using GAP to model groundwater arsenic concentration in Pakistan and China and compare these with published models that were generated through statistical programming also using logistic regression. Despite the statistical programming approach offering more options for manipulating and modifying the data and models, the prediction maps produced using GAP are remarkably similar and require substantially less time to generate, due to GAP's simple, quick-to-use modeling interface (*www.eawag.ch/en/research/humanwelfare/drinkingwater/gap*).

Code of abstract: T3.5.7
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

A multi-scale perspective for the modeling of managed aquifer recharge (MAR) applications

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KEY WORDS managed aquifer recharge, groundwater modeling, multi-scale approach, model limitations

ABSTRACT

Managed aquifer recharge (MAR) represents a valuable tool for the sustainable management of water resources. In a broader context, MAR can be defined as the purposeful recharge of an aquifer for later recovery or environmental benefits. The complex processes occurring at MAR schemes are generally studied either through direct observations or, based on simplifying assumptions, using physical and mathematical models. These models provide an important contribution towards different problem types, such as basic understanding of the system (for example, water flow pattern through permeable soils), estimation of system's properties (i.e. reduction of infiltration capacity due to clogging) or forecasting the future (i.e. assessing the impact of MAR on the groundwater system). However, the major drawback of many of such models is given by an incorrect estimation of their limitations, very much depending on the type and amount of assumptions made.

The approach proposed in this paper introduces a multi-scale perspective for modeling of MAR based on a combination of physical and mathematical models of different complexities and boundary conditions. The setup includes four physical models (two for each infiltration type) that are run under laboratory and field conditions, as well as a comprehensive web-based collection of analytical and numerical models. In order to understand the limitations of each model system, the boundary conditions and the geometry of the test field models were kept different than for the models run in the laboratory while the soil type, water quality and infiltration pattern were identical. The efficiency of the system at different scales and under various infiltration scenarios was assessed using the reduction rate of the infiltration velocity. In all cases, mathematical models were used for spatial and temporal characterisation of water flow conditions in the tests conducted.

The results of the investigations permitted the evaluation of each model's limitation as well as the ability of mathematical models to describe the processes occurring at laboratory and test field scale. Moreover, a sensitivity analysis allowed estimating the role of each parameter as well as making practical recommendations for improving the efficiency of the MAR schemes simulated.

Code of abstract: T3.5.8
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Description of spatial variability of nitrate in Campina de Faro aquifer, Portugal by a non-linear geostatistical methodology

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KEY WORDS: agriculture, nitrate, geostatistics, variogram, transition probability

ABSTRACT

We study here the relation in space that high values of NO3 have with the other values. A non-linear geostatistical approach is used. Different quantiles of the histogram are coded by indicators. The spatial structure of each indicator and its spatial covariation with the others are studied by computing experimental indicator variograms and crossvariograms. This analysis is applied to dissect the spatial structure of nitrate data sampled in Campina of Faro aquifer where intensive agriculture occurs to check if: a) When going from low values areas to high values ones, intermediate values are not necessarily crossed; b) That having trespass a certain cut-off, i.e. inside the corresponding areas in space, the high nitrate concentrations can be considered to be positioned independently from the other values; c) A kriging model with no transition in space is well adapted to the data. If yes a model based on the regressions of each indicator on the one immediately below it is applied e.g. in this model one can estimate the probability for the NO3 concentrations to trespass a given cut-off at a given location when knowing that the concentration trespasses lower cut-offs at surrounding points.

Code of abstract: T3.5.9
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Dewatering Design for an Open Pit Coal Mine and Assessment of Anticipated Impacts on the Groundwater Resources

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KEY WORDS - Central Anatolia, Feflow, dewatering wells

ABSTRACT

In a coal basin located in Central Anatolia, 100 million tons of coal is planned to be extracted via open cut and underground mining during a mine life of 26 years. The mining will be started in open pit and completed within 11 years. In order to satisfy dry working conditions for a safe and operational mining, prediction of the groundwater inflow rate to the open pit and proper design of a dewatering system play a critical role. This study intends to design a dewatering system for the open pit and evaluate anticipated impacts of dewatering on the groundwater resources.

A 3D numerical groundwater flow model of the site was constructed using Feflow software, and yearly dewatering requirements were determined under transient conditions. In the simulations, two types of dewatering wells were considered. Type I wells were permanent wells, which surround the open pit boundary and increase in number as the excavation proceeds. On the other hand, Type II wells were located at the periphery of yearly excavated area, which were started to operate one year before the excavation and were in operation about 2 years. The simulation results indicate that 894 wells were required to satisfy dry working conditions, where the pumping rates throughout the mine life increased from 60 L/s to 735 L/s with an average of 322 L/s. The impacts of open pit dewatering on groundwater resources were assessed in terms of spring discharge and base flow rates in the Kirmir Stream. As a result of dewatering, a majority of village water supply to springs and fountains will dry up in the area. In addition, the base flow rates to the Kirmir stream decreased by 15 %.

Code of abstract: T3.5.10
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Effects of well ageing on the hydraulics of water wells

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KEY WORDS -incrustations, well ageing, analytical solutions, head losses

ABSTRACT

Water well ageing is mainly attributed to biologically- and chemically-induced incrustations as well as suspended particles around the well. These incrustations can clog the different water well components (i.e. pipes, screen slots, gravel pack, adjacent aquifer), which will then increase drawdown (head losses) and therefore lead to higher pumping costs. This study focuses on the impact of clogging in the gravel pack, screen slots and well pipe components. Quantification of head losses for each component is done using available analytical solutions.

Gravel pack head losses are calculated using the Forchheimer-Engelund equation, which consists of two terms accounting for linear and non-linear laminar flow respectively. In this study, the Forchheimer-Engelund equation uses the gravel pack hydraulic conductivity as the main dependent variable since it is directly affected by clogging processes. The gravel pack hydraulic conductivity is estimated using the Kozeny-Carman equation, which takes into account the roughness, pore shape and porosity of the gravel pack. For simplification purposes, both the roughness and pore shape, which show a linear dependency and do not vary in a wide range, are considered negligible. On the other hand, the hydraulic conductivity shows a cubic dependency with the porosity.

Screen losses are determined using the orifice equation, in which the effective open area of the screen varies from 100% to almost 0%. Finally, the losses in the well pipe are calculated using the Darcy-Weisbach equation for various effective pipe diameter values. The previous methodology is justified since clogging processes can reduce both the screen slots and the effective pipe diameter respectively.

For porosities lower than approximately 15%, the non-linear term of the Forchheimer-Engelund equation starts to show significant variations with respect to the linear term. For porosities lower than 12%, the non-linear term dominates, showing drastic increases in the head losses. This indicates that calculations of clogged gravel pack head losses considering only the linear term could be underestimated. In case of the screen slots, a dramatic head loss increase is observed when the screen open area is reduced by approximately 98%. Head losses in the well pipe start to increase significantly when only 50% of the effective diameter is available. These preliminary results show that porosity is the most sensitive parameter affecting drawdown during well ageing. These findings are relevant for well optimization.

Code of abstract: T3.5.11
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Groundwater flow and time series models: complementary techniques to derive groundwater dynamics

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KEY WORDS - modelling, hydraulic head dynamics, impact multiple stresses, Belgium

ABSTRACT
Physical based three-dimensional groundwater models are routinely applied to derive regional and three-dimensional groundwater system dynamics, i.e. the behavior of a groundwater system subjected to a number of stresses. In time series analysis the relation between one or more variables (e.g. recharge, evaporation, extraction, etc.) and another variable (e.g. head) is determined using a regression model. It is a stochastic approach that does not need exact knowledge of subsurface characteristics or boundary conditions of the groundwater system.

Both methods have their pros and cons. A groundwater flow model gives insight in the three-dimensional behavior of a system whereas a time series analysis is restricted to specific locations (i.e. observation wells). Time series analysis on the other hand makes it possible to study high frequency head variations. Groundwater flow models need estimates of many different parameters and boundary conditions. Groundwater flow models and time series analyses are in many cases used alongside each other although the mentioned pros and cons suggest interesting complementarity.

Both techniques are applied in an iterative way to study groundwater dynamics around the extraction site Lembeke-Oosteeklo, Belgium, where water is extracted from a shallow phreatic aquifer. A MODFLOW flow model is developed and time series from 60 wells are analysed with the PIRFICT method (predefined impulse response function in continuous time). The zeroth moments of the impulse response functions (effect of stationary excitation of unit strength) are used as a calibration target for the MODFLOW model. Drawdowns and predevelopment heads calculated with both methods are compared.

Combining both methods results in an improved understanding of the impact of different stresses on head fluctuations. Regional drawdowns can for instance be derived more reliable because the impact of the extraction is known in more detail at a number of location through time series analyses. Also, the drawdown of the water table could be estimated whereas its derivation based on the calibration of heads with the flow model alone remains inconclusive. Finally, the MODFLOW model helps in the evaluation if different time series models are possible because the regional context is better known from the groundwater flow simulation.

Code of abstract: T3.5.12
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Groundwater modelling to facilitate regulatory change to realise operational efficiency at the Aldinga Managed Aquifer Recharge System

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KEY WORDS - groundwater numerical modelling, managed aquifer recharge, treated wastewater, groundwater management

ABSTRACT

This paper presents the results of numerical groundwater modelling completed to support changes to the operating conditions for managed aquifer recharge systems using reclaimed water in the McLaren Vale Prescribed Wells Area of South Australia. Under the existing management rules extraction of 100% of the total annual volume of treated wastewater recharged is required. Because the native groundwater salinity at the recharge site is greater than 2,000 mg/L, after recovery of approximately 60 to 70% of the total annual recharged volume, the salinity exceeds the irrigation threshold of 1,100 mg/L. Additional management of the residual volume of water that exceeds 1,100 mg/L is required which abolishes any benefit associated with storing the water in the aquifer. A three-layer model was constructed using the MODFLOW code. Following calibration and sensitivity analysis solute transport modelling using the MT3D code was applied to examine the implications of leaving a proportion of the 400,000 m^3/a. recharged water in the aquifer once the salinity of the recovered water exceeded 1,100 mg/L. In each of the four predictive simulations a set percentage of the total volume recharged was recovered for the initial five years of operation before increasing recovery to 100% of the annual recharge volume. Results of the modelling showed that moving to 100% recovery could only be sustained for two subsequent years. After which time, due to migration of the recharge water beyond the capture zone of the production wells, only 60 to 70% of the recharge volume could be recovered at a salinity threshold less than 1,100 mg/L. Migration of the residual injectant plume beyond the capture zone of the recharge/recovery wells was influenced by two factors; 1) the induced hydraulic gradient associated with the recharge and; 2) pumping by third parties south-west of the managed aquifer recharge site. It was concluded that the most practical option to achieve the required recovery volumes was to install two new production wells in the central portion of the site and operate the system as a quasi-aquifer storage transfer and recovery scheme. Under this operational approach, a higher percentage of the annual recharge volume occurs into the three production wells on the eastern boundary whilst the new central wells recover the bulk of the total injected volume.

Code of abstract: T3.5.13
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Hydrogeological triggers of the Deisermillen landslide in the Mosel River valley, Luxembourg

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KEY WORDS: numerical modeling; hydrogeological triggers; landslides; preferential flow; dual-permeability

ABSTRACT

The landslide of Deisermillen occurred in 1964 in the vicinity of Grevenmacher, Luxembourg (Mosel River valley). It was one of the most remarkable recent landslides in Luxembourg causing destruction of several buildings and regional motor road.
Various hydrogeological triggers could have contributed to the landslide initiation. The Mosel River level was raised by 4.45 meters after construction of a river sluice. Consequently increased groundwater tables could have significantly reduced cohesive strength of the sediments and increased the pore water pressures in the foot of slope. Moreover springs discharging in the landslide affected area and increased precipitations during autumn of 1964 could have triggered the landslide as well.
The objective of this study is to determine which factors caused the Deisermillen landslide and whether an actual landslide risk exists.
We applied 3D fully coupled hydrogeological model (HydroGeoSphere software) to investigate the hydrogeological conditions of the landslide and to use it for subsequent slope stability simulation. The model considers saturated, unsaturated and preferential flow, changing precipitation amounts, water infiltration from the Mosel River and springs discharging in the landslide area.
To test suitability of different conceptualization approaches of groundwater flow, two modeling scenarios using homogenous porous media and preferential flow paths were elaborated.
In the scenario with preferential flow paths dual permeability preferential flow conceptualization approach was applied, namely preferential flow paths are assumed to be planes with a defined spacing that subdivide the porous medium into uniform blocks.
The effectiveness of both modeling scenarios was evaluated using PEST code. This allowed to estimate whether scenario with porous media or preferential flow paths corresponds better with piezometer observations.
Groundwater heads from hydrogeological model were integrated in subsequent slope stability simulation applying the GeoStudio software.
The results illustrate the importance of considering a detailed scale hydrogeological simulation in the hillslope stability analysis to avoid landslide risk underestimation.

Code of abstract: T3.5.14
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Long term groundwater level reanalysis over France using the multimodel parallel plateforme Aqui-FR

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KEY WORDS Aquifer modelling; forecast; management

ABSTRACT

The Aqui-FR project aims at taking benefits of existing groundwater modeling applications used by stakeholders, to develop new products in order to provide useful information for water resources management. Indeed, it aims at providing forecasts of the groundwater resources from 10 days ahead up to the seasonal scale. To do that, Aqui-FR includes currently 3 hydrogeological models, covering 13 multilayers sedimentary aquifers and 6 karstic aquifers in France. These applications were assembled within the Open-Palm parallel dynamic coupler, and coupled to the Surfex land surface model that provides the recharge. The whole system is expected to run operationally at Météo France. As a first step, a long term reanalysis is performed to i) assess the full modeling system ii) to provide reference in order to compare the forecast to known past situations and known past statistics.
Additionally, the same system can be used to perform climatic change impact studies, allowing comparing the impact in several aquifer systems.
Specific indicators to communicate forecasts to water resources management are being developed in close connection with stakeholders.
We will present here the long term ground water head and surface water flow reanalysis as well as some preliminary results of the impact of climate change on aquifers will also be presented.

Code of abstract: T3.5.15
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Multi-objective optimization of aquifer storage transfer and recovery systems based on evolutionary algorithm

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KEY WORDS - optimization, evolutionary algorithm, MODFLOW, MT3DMS, MAR, ASTR

ABSTRACT

Designing an aquifer storage transfer and recovery (ASTR) site can be treated as a multi-objective optimization problem that requires, among others, finding appropriate locations of water injection and abstraction wells and optimal pumping and injection rates that result in maximal efficiency of the designed system. Efficiency of an ASTR system involves quantitative and qualitative aspects, which are ratio of recovered/injected water volumes and quality of the recovered water respectively. These aspects determine objectives of the optimization problem, which in this case are maximization of resulting groundwater storage in the aquifer and maximization of quality of the extracted water. The objective of this study is to test and demonstrate capability of an evolutionary algorithm to solve this kind of optimization problems. The test case is a hypothetical ASTR site with given aquifer properties, water volumes available for injection and number of planned injection/abstraction wells. Tested scenarios include injection of potable water into a brackish aquifer and injection of contaminated water into a freshwater aquifer. The optimized variables include coordinates of the simulated wells and pumping/injection rates of each simulated well and time step. The scenarios are simulated by applying a numerical transient groundwater flow and solute transport model. For modeling purposes MODFLOW and MT3DMS software has been used.

Code of abstract: T3.5.16
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Web-based compilation of empirical and analytical equations for the sustainable management of groundwater resources

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KEY WORDS web-based tools, cloud modeling, managed aquifer recharge, decision support system (DSS)

ABSTRACT

The INOWAS-DSS platform provides a compilation of open-source web-based tools for planning, optimization and management of managed aquifer recharge (MAR) schemes. All tools are running on a web server and can be accessed via standard web browsers. Besides the numerical simulation core (based on MODFLOW) the platform provides simple empirical and analytical tools to assess various groundwater-related issues. A focus is set on issues that arise during the implementation of MAR.

The implemented tools facilitate, for example, the assessment of saltwater intrusion induced by pumping or sea-level rise, the calculation of travel time through unconfined aquifers and pumping-induced river drawdown. A parameter estimation tool helps the user to calculate the saturated hydraulic conductivity based on measured data such as grain-size distribution, permeameter tests, double-ring infiltrometer as well as pumping and slug tests. The data-driven MAR method selection tool helps to narrow down the list of MAR methods which are suitable at a proposed location. The groundwater mounding calculator can be used to estimate the rise of groundwater levels beneath infiltration basins. The clogging potential of infiltration wells can be estimated using the measured membrane filtration index of infiltration water. The calculation of the maximum well head injection pressure helps to avoid hydraulic fracturing during the injection of water into infiltration wells. The suitability of a proposed location for injection wells in brackish or saline aquifers can be estimated using the ASR efficiency assessment tool. To determine the contaminant concentration downgradient of a constant source, an analytical tool solving the advection-dispersion equation can be utilized. Further tools are under development and will be added in the near future.

All tools are incorporated into a decision support environment and can be used individually but are also allocated to MAR-specific application workflows. Thus, the user is provided with a pre-selected list of tools that suit his MAR-related issue as well as with detailed support sites that contain the theoretical background of the tools, possible applications and examples. This tool box provides the user with easy open-source tools that facilitate the sustainable management of groundwater resources.

Code of abstract: T3.5.17
Type of presentation: Oral presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Weekly, monthly and seasonal forecasting of groundwater levels using artificial neural networks

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KEY WORDS groundwater levels, forecast, artificial neural networks, wavelet transform

ABSTRACT
The reliability of modelling and predicting groundwater levels using physically-based numerical groundwater flow models strongly depends on field data availability for model parameterization. Especially when studying at the medium and large scale, models often fail because of missing or "incomplete" information regarding, for instance, spatial extent of the individual geological formations and their hydraulic properties. Approaches based on artificial intelligence, such as artificial neural networks, are a promising alternative, as they reduce the question to a simple input-output-relationship, while descriptions of the physical process are omitted.
Reliably predicting groundwater levels is indispensable for, e.g. derivation of water availability and irrigation requirements for drinking water supply and agriculture, delineation of potential land subsidence zones caused by extreme low groundwater levels related to droughts and/or pumping, delineation of potential groundwater flooding zones for traffic infrastructure, buildings and agricultural land, and the development of appropriate avoidance and adaptation strategies.
In this contribution, the versatility of different artificial neural network types (feed-forward and recurrent neural networks, with and without preceding wavelet transform of the input data set) was evaluated at several observation wells in Germany. These observation wells are characterized by long, regular and dense records and without known significant influence of local abstractions. Weekly, monthly and seasonal hindcasts of the groundwater level were conducted for a fixed period in the summer for several years and results indicate superiority of recurrent neural networks (nonlinear autoregressive networks with exogenous input - NARX), with relative root mean square errors below 0.06 m and corresponding coefficients of determination ranging between 0.84-0.98. Wavelet transforms seem to be a valuable tool to improve feed-forward network results, but are less suitable for improving NARX.
Additionally, the selection of the piezometers and their ability to represent the general flow dynamics in the respective aquifer will be discussed.

Code of abstract: T3.5.18
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Can numerical modelling be used in the assessment and remediation of hydrocarbon contaminated sites, and if so, in what capacity?

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KEY WORDS - Petroleum, contamination, free phase, numerical model, remediation

ABSTRACT

Petroleum serves as a great source of energy however, with such principle importance; it poses a problem as a global contaminant. Hydrocarbon contamination is a huge threat to groundwater as it contains toxic substances that are insoluble in water referred to as the free phase. When spilled, hydrocarbons will move downward through the unsaturated zone under the influence of gravity and capillary forces, trapping small amounts in the pore spaces. There is a long term effect on ecosystems as the insoluble free phase mass slowly decays into the aquifer making it more difficult to model and control. The net result is that some hydrocarbon fractions are transported faster than others and a contamination plume of varying intensity may spread over a large area. The ultimate aim of this study was to develop a methodology to assess the movement and remediation of hydrocarbons in the subsurface with the use of a numerical model, to improve the management of areas contaminated by hydrocarbons. This includes the migration and delineation of the free phase and dissolved plume. Additionally, it was necessary to simulate a number of chemical flushing remediation options to elevate whether modeling can be used to determine the best remediation option based on the type of solvent used and concentration. The Environmental Agency, the leading public body for protecting and improving the environment in England and Wales, does not mention the use of modelling in a manual titled 'An illustrated handbook of DNAPL transport and fate in the subsurface'. A document compiled by The United States Environmental Protection Agency highlights the complexity and sensitivity of NAPLs (Non Aqueous phase liquids) to subsurface heterogeneities within a site making it extremely difficult to model however it can be used as a valuable learning tool if specific sites need anticipated output data. According to the Manual for site assessment at DNAPL contaminated sites in South Africa, MODFLOW and UTCHEM can be used as a facilitator in managing and containing hydrocarbon contamination. The software package UTCHEM was therefore used to model the migration of the non-aqueous and aqueous hydrocarbon phases and surfactant and co-solvent enhanced remediation, while MODFLOW was used to facilitate the migration and extraction of the dissolved plume.

Code of abstract: T3.5.19
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Development of a Decision Suport System (DSS) in a GIS platform to integrate transport modelling results of soil-surface and groundwater contaminants

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KEY WORDS - Contamination, Decision Support System, Modelling, Integrated Transport Models, Management

ABSTRACT
Many areas in southwest Europe are still affected these days by the environmental impact of past and/ or present contamination associated with chemical industry and mining activities. These contaminations affect not only soil and its functions but also surface and groundwater resources, the atmosphere and human health of surrounding populations through breathing or ingestion. Public environmental and water authorities are currently facing significant technical and costly challenges to carry out accurate inventories and characterization of contaminated sites and to define remediation processes and minimization measures. The Soil Take Care, a transnational cooperation project funded by Interreg V SUDOE, selected three case studies in France, Spain and Portugal to investigate, monitor and model in detail, and aims to integrate transport modelling results of air-soil-water contaminants in a Decision Support System (DSS) using a GIS platform to help to implement remediation and social measures. The outputs of the project comprehend tools and methodologies for 1) a complete diagnosis of contamination and remediation; 2) elaboration of maps of vulnerability and socio-economic analysis to serve public authorities and stakeholders; and 3) databases in open-access to be used in water management, investigation and to integrate in other information systems.

Code of abstract: T3.5.20
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

GEOSTATISTICAL CHARACTERIZATION OF CONTAMINATION SOURCES: APPLICATION TO A MUNICIPAL SOLID WASTE LANDFILL IN SPAIN

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ABSTRACT

Solid waste landfills are one of the most important potential sources of soil and groundwater contamination. Despite groundwater quality problems may be caused by the presence of a landfill and risk analysis should be one of the numerical techniques required by legislation to obtain the environmental permits, geostatistical analysis has seldom been used to characterize the hydrogeological properties of the saturated or unsaturated mass of waste in real case studies.

This work shows the first attempt on a real case landfill located in Valencia region to perform a geostatistical analysis of the hydrogeological parameters of the municipal solid waste. A set of different geostatistical estimation and simulation methods are considered in order to obtain the risks maps that may contribute to support the decision-making-process.

Code of abstract: T3.5.21
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Groundwater conditions in section of Cracow – Tarnow highway A4 (Upper Vistula Catchement)

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KEY WORDS - numerical model, highway A4, hydrogeological conditions, Upper Vistula Catchment

ABSTRACT

Nowadays, progressive climate changes become increasingly noticeable. They lead to a sudden torrential rainfall, spate rivers and in extreme situations to floods and flooding. This issue has a great social importance, especially in areas affected by the occurrence of frequent floods in the Upper Vistula catchment. Part of these catchment is changed as a result of the current construction and use of the highway A-4. The first step to understanding scale of this hazard is to determine direction of groundwater flow.

The goal of this work was description of the groundwater circulation system and the analysis of hydrogeological condition. To estimate this problem, author proposes the use of numerical modeling.

Based on the collected field and archival hydrogeological, hydrological and sozological data a conceptual model was built. To investigate the current situation, a hydrogeological, hydrological and sozological mapping was carried out. Subsequently a numerical model of groundwater flow was developed. In this case author used the specialized software „Visual MODFLOW", v.4.3.

It is therefore necessary to develop an integrated approach to flood risk analysis, which would emphasize the interaction between groundwater and surface water in regions of the implementation and operation of road investments.

In the future, model results will be compared with flood hazard maps for worst - case scenario.

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Code of abstract: T3.5.22
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Mathematical modeling of the Mar del Plata Aquifer and transference to the Water Manager Authorities

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KEY WORDS: groundwater modeling, coastal aquifer management, climate change scenarios

ABSTRACT
The management of the coastal aquifer in Mar del Plata, Argentina, is a difficult issue because of the pressure resulting from the high demand of a 700,000 inhabitants population and the vulnerability of the coastal aquifer to seawater intrusion. An important marine intrusion into the aquifer happened during the 50ies with the consequence of abandoning 53 wells and the need of the displacement of the exploitation zone many kilometers to the north of the city. After that new exploitation zones have being opened, the sustainability of the resource under the climate change constitute a major challenge for the groundwater manager, the Company Obras Sanitarias Mar del Plata-Batán.
In the context of the initiative WaterClima-Lac, financed by the European Union through the EUROPEAID program, an important agreement was achieved between WaterClima-Lac, coastal zones and Obras Sanitarias for the development of a mathematical model for simulating new pumping well areas and the effect of the climate change scenarios. The mathematical model was built in a ModelMuse® software platform considering a stationary state initial and dynamic state after. Boundary conditions were defined according to previous hydrogeological works and the historic records of the pumping rate for all the wells were an input for the calculation. In the model has been used temporal series of evapotranspiration and recharged in the different areas included into the model. As a recharge, into the urban zones was considered losses from water distribution lines and wastewater service network of near to 30% of water used to supply service. The model calibration was done by using the recorded piezometric levels (1913-2005) against the simulated levels, obtaining a satisfactory adjustment that is a promissory contribution for the aquifer management. In the next future the emissions scenarios RCP2.6 and RCP4.5 will be introduced for a specific predictor model, as well as a new battery well, (West system). It is expected that this mathematical model can be used as a tool in the management and control of groundwater in the Mar del Plata and allow considered different alternatives before taking a decision referred to increased the captation area for water supply.
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Code of abstract: T3.5.23
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Mulitivariate drainage forecasts of the open limestone pit mine „Celiny" (South Poland)

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KEY WORDS - open pit mine, drainage, groundwater circulation, multivariate forecasts, numerical model

ABSTRACT

The drainage of mining excavations has a significant impact on adjacent groundwater circulation systems, the scale of which depends on the constant factors that include *inter alia*: geological structure and hydrogeological conditions. Precipitation (and its amount) is a time variable parameter, which has a major influence on groundwater table elevations and fluctuations. The correct long-term forecasts of mine dewatering, therefore, requires conducting multivariate simulations taking into account the different states of the hydrodynamic conditions.

The goal of this work was the analysis of drainage forecasts performed for an open limestone pit mine "Celiny" situated near Chmielnik (the region of Kielce – S. Poland) for three hydrodynamic conditions related to the multi-year (1951-2015) precipitation: the average, dry and wet, for three ordinates of the open pit drainage: 241.5, 230.5 and 219.5 m a.s.l., and diverse exploitation status of existing groundwater intakes, and taking into account the open pits operating in the research area. The simulations (15 in total) were carried out based on a numerical model of the groundwater circulation system of the Chmielnik region developed using the specialized software - Visual MODFLOW. The numerical model maps the five-layer groundwater circulation system in conjunction with surface watercourses. Such division reflects appropriately the variability of hydrogeological parameters within the geological structures. The modelled area of 130 km^2 was divided into square grids of 50 m.

The results of forecasts presented in a tabular form show the balances of water inflows into the pit. The maps for hydrodynamic neogene-mesozoic aquifers featured in the modelled area include extents of the depression cone. Results indicate that the groundwater recharge by the rivers increases with the increase of precipitation. Moreover, the greater is the excavation depth, the higher groundwater recharge is observed.

The carried out analysis will be the basis for assessing the impact of a planned drainage of the open limestone pit mine "Celiny" on the soil-water system, and for designing a sustainable distribution system of mine waters to protect groundwater depending ecosystems.

This study was financially supported by AGH research grant no. 15.11.140.828.

Code of abstract: T3.5.24
Type of presentation: Poster presentation
Topic: T3. Groundwater Modelling
Session: T3.5. Groundwater modelling and management

Use of Geographic Information Systems in Geology and Hydrogeology Engineering

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KEY WORDS - geographic information systems, DSI, groundwater, GIS analysis, GIS maps

ABSTRACT

GIS, which is used in all engineering disciplines, is one of the important tools in geological engineering applications.Studies in geological engineering are carried out in two ways as underground water and geotechnical studies. Geological and topographical cross sections are formed within the groundwater studies, including determination of groundwater flow direction, determination of feeding and discharging areas, formation of groundwater level distribution maps, formation of precipitation maps using precipitation station data, formation of distribution maps using water chemistry analysis results.Within the scope of geotechnical studies; Determination of axle location, determination of injection points, location of natural building materials fields, determination of usage areas of natural materials in natural building materials field, determination of depth and depth of basic drilling wells, determination of thickness in material fields, determination of amount of excavation to be done under axle location and body , Research in material works, determination of observation wells, and so on.Classification, interrogation, spatial analysis, data transformations, multiple data overlapping, scenario generation and estimation can be done using the data obtained with GIS.All work is done in the current situation. The groundwater chemical distribution maps provide information about the water chemistry in the newly opened wells for future studies. The groundwater level curves provide information about the level in the well to be opened in the future. It is easy to solve problems and solve problems with CBS, which provides all the same information and ease of use.
In summary; All work done with existing infrastructure projects is quickly resolved and built to form the basis of future work.

Code of abstract: T4.1.1
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.1. Monitoring of groundwater levels and flows

Assessing the potential groundwater withdrawals from water wells : a simplified method

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KEY WORDS potential groundwater withdrawals, potential yield, yield assessment, water well, methodology

ABSTRACT

Different methods exist to assess the volumes of groundwater that can be potentially withdrawn from an aquifer. One challenge is then to affect the available groundwater to the different wells and drinking water production systems pumping in the aquifer. This is possible with a 2D or 3D model of the aquifer, but such models are generally complex to develop and to calibrate. Simplified graphical, statistical or analytical methods also exist, depending on the water well characteristics and on the hydrodynamic parameters of the aquifer. These simplified methods generally give a single value of the groundwater withdrawal assessment, with no relation to the hydrological situation of the aquifer. Moreover, constraints on their range of validity limit their deployment.

A new simplified methodology is proposed for the determination of the potential groundwater yield at a water well, variable over time with the hydrological situation, i.e. with the pseudo-static level of the groundwater table measured on the well. Consequently, the potential groundwater withdrawal volumes will be higher during the wet season and lower during the dry season, depending of the pseudo-static level variations.

Many analytical solutions exist to describe transient flows in aquifers, making it possible to calculate a drawdown as a function of the pumping rate, at a given distance from the pumping well. By reversing these relations, it is possible to express a potential withdrawal volume as a function of a fixed maximum suitable drawdown. The Cooper-Jacob solution (1946), a simplification of the Theis solution (1935), commonly used in quantitative hydrogeology, was used to design this new methodology. Input data are well characteristics, local hydrogeology as well as operational data.

Simple, robust and transposable, the proposed methodology allows indirect consideration of the hydrological situation of the aquifer, and of its induced natural and anthropogenic factors. This methodology was designed to ensure sustainable pumping of groundwater for drinking water production, and could be applied to any water use, or integrated in a decision support tool for water resources management strategies.

Code of abstract: T4.1.2
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.1. Monitoring of groundwater levels and flows

Contributions to the Characterisation of the Vadose Zone for Hydrogeological Applications

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KEY WORDS - geotechnical centrifuge, cubic law, fracture flow, partial saturation

ABSTRACT
Hydrogeologists have moved past merely investigating for water supply and quantification of sustainable yields. In the 21st century, and with rapid urbanisation and climate change, hydrogeologists are expected to work in cross-disciplinary fields of geochemistry, aquatic biodiversity, surface water – groundwater interaction, groundwater economics, law and management. In addressing important hydrological parameters such as recharge, recharge rates, advection of contaminants and interflow, the role of the vadose zone becomes increasingly important. A series of case studies and physical models were used to evaluate the movement of water at variable saturation through media with primary, secondary and tertiary porosity. Scales of models varied based on different volumes of observation and relevance from discreet fractures to regional hillslopes. Centrifugal acceleration was employed in some of the models to scale predetermined variables. Models included consolidation of heterogeneous soil successions, discreet fractures and their intersections, flow from soil into discreet rock fractures, and column testing of dolomite residuum. Advances are made in the qualitative and often quantitative assessment of interflow, soil-to-rock percolation, discrete fracture flow, and flow through dolomite residuum. Further to this, insight is gained into empirical quantification of hydraulic parameters through, for instance, the cubic law; the relevance of flow regimes (turbulent versus laminar) at various Reynolds numbers; and breaching of interfaces to promote vertical percolation of water stored in partially saturated geological media. Applications include improved understanding of pore water pressure distributions in media, induced seepage under consolidation, ingress water eroding soil into bedrock cavities resulting in sinkholes or surface subsidence, drainage of slopes and cuttings, water influencing infrastructure, indirect and localised recharge rates, aquifer susceptibility to contamination from surface, and urban hydrology in general. The paper addresses some key findings and examples from the various experiments perform, aiming to improve understanding of the role of the vadose zone and how it is affected by anthropogenic activities.

Code of abstract: T4.1.3
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.1. Monitoring of groundwater levels and flows

The Use of Thermograph and Hydrograph to Estimate Water Fluxes Across the Streambed at the Tributary of Chichiawan Creek, Taiwan

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KEY WORDS: surface water and groundwater interaction, heat transfer, streambed, VS2DH, Shei-Pa National Park (Taiwan)

ABSTRACT
Interactions between groundwater and surface water play a fundamental role in the functioning of riparian ecosystems. Chichiawan Watershed in Taiwan is the only habitat for the endangered species of formosan land-locked salmon. The flowpath and water fluxes across the sediment-water interface are critical and important factors for salmon spawning, as downwelling streamwater or upwelling groundwater can affect the population size of salmon and the extension of habitat. Streambed water exchanges is the movement of water from a river into the beneath sediments and then back into the river, and in order to assessing such complicated dynamics between stream and sediments, the environmental tracer of heat is used to determine the water fluxes through the streambed and to estimate the associated hydraulic characteristics. Three piezometers along the Yusheng Creek, the tributarary of Chichiawan Creek are installed and the river stage, groundwater level, river temperature, and groundwater temperature are measured. The hydrographs, thermographs, temperature envelope, and temperature contour plots are obtained to calculate the streambed water exchanges and to analyze the spatial and temporal transition processes of stream and groundwater interaction. The numerical model of VS2DH and automatic parameter estimation software of PEST are used to quantify the vertical fluxes and hydraulic conductivities of sediments. The results show that the Yusheng Creek within the monitoring section is a losing stream and its downwelling flux increases from up- to down-stream. When rainfall is deficient over an extended period of time, the partial sections of stream channel changed from continuous to intermittent. Meanwhile, the water table drawdowns rapidly and an unsaturated zone beneath the streambed surface is formed. The stream situates in a temporary condition of losing and disconnected and the heat transfer transits from advection dominated to conduction dominated nowadays. The phenomena mentioned above are recorded not only in water level data but in temperature data, and confirmed the use of heat as a tracer to evaluate the flux exchanges across the streambed is feasible. Although a clogging layer of streambed consisted of algae and fine grain is appeared, their processes in the sediment need further study.

Code of abstract: T4.1.4
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.1. Monitoring of groundwater levels and flows

Identifying hydraulically active flow paths in boreholes using A-DTS thermal response tests

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KEY WORDS - rock thermal conductivity, hydraulically active fractures, ambient gradient flow, fractured rock, DTS.

ABSTRACT

Determination of hydraulically active intervals in boreholes under natural gradient conditions has been challenging, requiring intense field data collection. Recent advances in thermal response tests in temporarily sealed boreholes using active distributed temperature sensing (A-DTS) show improved identification of flow under ambient conditions in individual fractures (Coleman et al. 2015). This study advances the method by obtaining a detailed profile of effective thermal conductivity that accounts for the asymmetrical impact on heat transfer caused by the stagnant water column inside the borehole liner. The baseline effective thermal conductivity profiles derived from A-DTS match the laboratory rock thermal conductivity measured on intact saturated rock core samples. Intervals within the borehole that show enhanced heat dissipation above the rock matrix thermal conductivity baseline are attributed to forced convective heat transfer at fracture surfaces caused by groundwater flow. The results allow efficient identification of depth-discrete hydraulically active intervals along the entire borehole, which can assist with monitoring at contaminated sites, detecting risk to geotechnical infrastructure such as earth dams, and assessment of ground source heat pump system performance.

Code of abstract: T4.1.5
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.1. Monitoring of groundwater levels and flows

Study of groudnwater changes caused by 2016 M5.4 Gyeongju earthquake, South Korea

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KEY WORDS - M5.4 Gyeongju earthquake, South Korea, groundwater level change, changes in temperature and electrical conductivity, hydrogeologic system

ABSTRACT

The largest earthquake of magnitude M5.4 in the Gyeongju City area, South Korea occurred at 20:32:54 on September 12, 2016 (local time), since the beginning of instrumental earthquake monitoring in Korea peninsula. A magnitude 4.9 foreshock occurred about 1 hour before the magnitude 5.4 earthquake and more than 500 time aftershocks continuously occurred after the magnitude 5.4 earthquake. Groundwater changes including water level, temperature, and electrical conductivity were detected in Yeongdong area, Seocheon area and Jeju Island response to M5.4 Gyeongju earthquake. The distance between the study areas and the epicenter of M5.4 earthquake are about 130-150km in Yeongdong area, 240km in Seocheon area, and 350km in Jeju volcanic island. Groundwater changes were observed in the monitoring well of study area and the time interval between groundwater observation is measured from 1 to 30 minutes in each study areas.

In Yeongdong area, some of wells detected two successive changes in groundwater level and temperature by foreshock and main earthquake, however, others were observed only by main earthquake. The types of groundwater level change due to earthquake observed to be oscillatory and persistent in Yeongdong area. Also, simultaneous changes in groundwater level and temperature were observed in the wells located at the fault boundary across the Yeongdong area, and these changes seem to indicate changes in the hydrogeologic system. The electrical conductivity of lower part (bottom) in seawater intrusion monitoring well was instantaneously increased then vertical changes in temperature and electrical conductivity were observed through continuous vertical profile logging. In Jeju volcanic island, a farthest distance from the epicenter, abrupt changes in groundwater level was detected about 2-3 minutes after the M5.4 main earthquake.

Code of abstract: T4.2.1
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

A Holistic Approach to Groundwater Management

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KEY WORDS - Visual MODFLOW Flex, Hydro GeoAnalyst, AquiferTest, AquaChem, Waterloo Hydrogeologic

ABSTRACT

With research advancements in natural sciences, it has become more evident than ever before, holistic integrated methodologies with proper data management and visualization does aide in solving key environmental problems. It is essential to consolidate, analyze and visualize using different tools. Therefore, using software that can communicate cross-platform is efficient and powerful when working with large environmental data sets.

In order to meet the various deliverables for this project, an entire suite of environmental software products was used. We began by using Hydro GeoAnalyst (HGA) to consolidate and manage all the data within one centralized database. This tool allows us to create a flexible and customizable database, specifically to meet our project needs. HGA gives us the ability to easily standardize and consolidate large sets of data while ensuring integrity and consistency within the database. While the Data Transfer System helped us find and remove the duplicates we had in our data during the import process. Furthermore, we were able to generate well profiles, maps and cross sections with confidence knowing we have a QA/QC-ed data set stored in the database.

Then we pushed the water level observations to AquiferTest for analyzing, interpreting and visualizing the pumping test data to assess groundwater extraction impacts on heads, drawdown impacts on surrounding hydrologic features and to determine the physical properties of the aquifer. Next we connected the database to AquaChem to perform the essential geochemical analysis for the purposes of the project. It allowed us to create of a number of water quality plots and exceedance reports to better understand temporal and spatial behaviour patterns as well as interpret the processes that led to the composition of the groundwater.

And finally Visual MODFLOW Flex was used for simulating groundwater flow and contaminant transport at the site. Using HGA we exported the cross sections and incorporated them into the conceptual model. We also queried out the well locations, and head and concentration observations that were used in the calibration and validation of the model. The model was then used to evaluate the spatial and temporal extents of the TCE plume and create predictive modeling scenarios which helped us evaluate remediation options for our site.

Code of abstract: T4.2.2
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Assessment of contaminated sites in Slovakia – lessons learned from groundwater and surface water monitoring during 2014-2016

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KEY WORDS - Monitoring, Contaminated Sites, Groundwater, Slovakia

ABSTRACT
In the context of the Water Framework Directive and a comprehensive water protection in Slovakia it is necessary to address the problems related to point pollution sources (so called contaminated sites). Since 2012, several projects related to monitoring of contaminated sites are carried out by the State Geological Institute of Dionyz Stur. The aim of the projects is to design and implement the monitoring program for about 300 contaminated sites in Slovakia, to identify leakage of pollutants into the environment and their extent and to assess the trends in concentrations of pollutants. Within the projects, a huge amount of data on groundwater and surface water quality have been collected and analysed. Monitoring programs are compiled separately for each site based on the hydrogeological conceptual models. It was a challenge to set up suitable monitoring design for each site taking into consideration the objectives of monitoring, the required accuracy and reliability of monitoring results and the type and variability of endpoints. Number of proposed monitoring sites has essentially depended on the spatial extent of contamination, the number of pollution releases, type and distribution of contaminants, complexity of the hydrogeological structure and groundwater flow, behaviour of pollutants in the environment, access (including existing buildings and services, ownership and security establishment of the monitoring network), sensitivity of the receptor at risk and legislative requirements. Obtained data and monitoring results contribute to a comprehensive and systematic management and gradual removal of contaminated sites as well as reduction of risks to environment and human health.

Code of abstract: T4.2.3
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Baseline Groundwater Status in Private Water Wells in Regions of Potential Shale Gas Development (New Brunswick, Canada)

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KEY WORDS - groundwater quality, dissolved methane

ABSTRACT
It is important to establish regional groundwater status in areas of potential resource (e.g. natural gas) development. Groundwater quality and the occurrence of dissolved methane, ethane and propane were investigated by sampling private water wells in the province of New Brunswick, where groundwater is the source of drinking water for more than 60% of the population. In total 434 water wells, distributed over an area of about 6100 km^2, were sampled on at least one occasion. The wells were mainly completed to depths of less than 100 m in the sedimentary bedrock units of the Carboniferous Maritimes Basin. A subset of 15 wells, located within two subareas (Kent and Sussex), was sampled monthly for a period of one year.

The results indicate that untreated groundwater in the study areas did not generally present a significant public health concern. However, at least one Health Canada drinking water guideline was exceeded in 332 (76%) of the wells sampled. Methane was detected (> 0.001 mg/L) in 55% of the wells, with a median concentration of 0.006 mg/L and a maximum of 29 mg/L. δ^2H and δ^{13}C in methane were determined in 9% of the wells and both biogenic and thermogenic origins were indicated. The Sussex study area had the highest frequency of samples with methane concentrations > 1 mg/L. The majority of the higher methane concentrations within this area were from wells located where Horton Group bedrock is inferred to be present relatively close to the ground surface. The Horton Group contains the Albert Formation, a known host for oil and natural gas reserves in New Brunswick.

There was little temporal variability in the methane concentrations from 6 wells in the Kent area, with the relative standard deviations (RSD) ranging from 0 to 20%. The methane concentrations in the 9 Sussex area wells that were sampled monthly had RSD values ranging between 18 and 141%. The wells with temporally consistent water quality tended to be those with a single major water-bearing fracture zone (as noted on well driller logs), whereas wells with multiple water-bearing zones had more variable water chemistry. Temporal variations in methane were often accompanied by variations in the inorganic chemistry, suggesting that the changes in methane concentrations reflected changes in the well water composition as opposed to sampling artifacts.

Code of abstract: T4.2.4
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Evaluation of groundwater environment changes due to urbanization in the Tokyo metropolitan area, Japan: Application of long-term monitoring of subsurface temperature and groundwater levels

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KEY WORDS subsurface temperature, groundwater flow, long-term monitoring, urbanization, Tokyo metropolitan area

ABSTRACT

Urbanization and human activities in the Tokyo metropolitan area have induced various changes of groundwater environment, such as groundwater flow regime and subsurface temperature distribution. In addition, subsurface temperatures have been affected by surface warming caused by not only urbanization but also global warming. Thus, it is required essentially to clarify the mechanism and process of changes of subsurface thermal environment and to evaluate the present situation of that in this area for sustainable groundwater management.

Three-dimensional distribution of the subsurface temperature and its secular change have been observed by repeated measurements of temperature-depth profiles at observation wells of groundwater levels and land subsidence since 2000s in this study. We also have conducted subsurface temperature monitoring using high resolution and accuracy temperature logger (resolution: 0.001 degrees Celsius) for two or more years to find subsurface temperature change in detail. In addition, groundwater flow regime was evaluated based on the distribution of hydraulic heads in the wells.

Secular subsurface warming was found at shallow depths in the whole study area, not only in urbanized area but also suburban areas. Also, subsurface temperature beneath the urban center was particularly high even in the deep part. The results of the monitoring showed continuous warming tendency beneath both of the urban center and the suburbs. However, the warmings at 40m deep beneath the urban center showed fluctuations in a few-months interval. This trend was considered to be induced by heat supply from underground buildings. Differences of the trends between the urban center and the suburbs suggest the capability to separate effects of climate changes and urbanization in the Tokyo metropolitan area.

This study is conducted as a part of joint research projects and supported by JSPS KAKENHI Grant (No. 16K00595).

Code of abstract: T4.2.5
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Groundwater quality and contamination in the central part of the Oredezh river valley (St.Petersburg Region, Russia)

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KEY WORDS - - groundwater, chemical composition, contamination, monitoring

ABSTRACT

The studied area is situated in the central part of the Oredezh river valley located in the northwestern part of European Russia (70 km to the south from St.Petersburg). Geologically, this is a part of the Russian Platform formed by Precambrian basement and 500 m thick Paleozoic sedimentary cover. There are several aquifers, the most important of them are Quaternary and Mid-Devonian (Q_{III-IV}+D_2st) unconfined aquifer, Mid-Devonian (D_2nr) and Ordovician (O_{1-3}) confined aquifers that contain fresh water and are used for local water supply.

The right bank of the river is formed by Mid-Devonian red sandstones (D_2st); the plain terraces of the left bank are formed by Quaternary sediments of different genesis.

The area is subjected to agricultural contamination, which influences the groundwater quality. From 2007, annual summer groundwater sampling is carried out; there are also some winter samples. The groundwater quality of the left and right banks greatly differs due to the human activity and, partly, natural reasons.

The right bank is coved by forest and poorly populated; the groundwater is of very low TDS (below 100 mg/dm^3) and low hardness (< 1.5 mmol/dm^3). The predominant ions are bicarbonate and calcium. To our opinion, the chemical composition of this water represents the natural state of the aquifer.

The left bank is occupied by the village. The unconfined aquifer occurs in Quaternary sediments; the water is of higher TDS (about 150-400 mg/dm^3) and hardness (about 4 mmol/dm^3) than ones of the right bank. The predominant ions are also bicarbonate and calcium. Nearly all groundwater samples taken on the left bank have nitrate contents higher than MAC (in Russia – 45 mg/dm^3; WHO norms – 50 mg/dm^3). There are some regularities of the distribution of TDS values and nitrate contents in space and time. It can be explained by the existence of the long-term agricultural contamination and presence of the constant nitrate source in the recharge area. Contents of nitrites and ammonium ions on the left bank are below MAC. Regression analysis carried out for the spring with high nitrate contents showed the gradual decrease of nitrate contents in time (from 2007 to 2015). Hence, the main source of nitrogen contamination is old.

Other results of the statistical analysis will be shown in the presentation.

Code of abstract: T4.2.6
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Influences on Water Quality Samples from Open Borehole Wells in Fractured Crystalline Bedrock

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KEY WORDS contamination, sampling, borehole wells, fractured bedrock,

ABSTRACT
Wells in fractured crystalline bedrock are commonly completed as open boreholes. Open borehole wells that are used for monitoring are typically sampled for water quality by low flow pumping. Representative samples of the bedrock water quality are assumed and taken when water level and indicator parameters have stabilized. Open borehole wells used for domestic water supply are typically sampled for water quality from the tap after some arbitrary period of purging. In this study, case histories, field studies and modeling simulations demonstrate that commonly applied approaches in sampling open boreholes can result in highly misleading concentration determinations. Water quality results obtained from open boreholes that intersect multiple water contributing fractures represent flow weighted averages which are dependent on the hydraulic head of fractures, the transmissivity of fractures, the water quality of individual water contributing fractures and water levels achieved in the well during sampling. Owing to these factors, collecting samples while water levels vary or at different steady state levels will result in different average concentrations. Depending on how a well is purged and sampled, the concentration of constituents of interest can vary by orders of magnitude. Even when consistent sampling approaches are used from well to well, weighted averaging can be highly variable at each well location given variations in the other factors that influence averaging. Concentration averaging in open borehole wells can confound mapping contaminant distributions which further results in inaccurate contaminant risk assessments, poor correlations of contaminant distributions to anthropogenic or natural sources and erroneous water quality modeling. This study supports the need for downhole sampling of individual fractures to decipher water quality conditions. Low cost sampling and fracture characterization methods need to be further developed in order to foster widespread downhole sampling and to accurately model and assess risk associated with contaminants.

Code of abstract: T4.2.7
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Lysimeter research under simulated municipal landfill conditions

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KEY WORDS - lysimeters, leachates, municipal landfill

ABSTRACT
The need for an accurate assessment of the real impact of pollution sources on groundwater quickly increased after the entry into force of The Groundwater Directive 2006/118/EC. In particular, it applies to waste landfills, including municipal. According to the regulations, landfills are subject to mandatory monitoring of groundwater. Prior to depositing the waste in the landfill, tests are carried out to verify what type of landfill is appropriate for the tested waste. The commonly used is norm EN 12457 Characterisation of waste leaching compliance test for leaching of granular waste materials and sludges. These tests, as static leaching tests, are performed in laboratories for a about 100 gram sample of waste. Consequently, the obtained concentration of contaminants is small. An alternative to batch tests are lizymetric tests, which provide a more comprehensive view of the concentration of contaminants in leachates.

In this paper, the results for the lysimeter experiment under simulated municipal landfill conditions were presented. The lysimetric station consists of two lisymeters filled with municipal waste from a complex of municipal landfills in Tychy Urbanowice (Southern Poland), where the experiment is performed. The landfill complex consists of an unexploited landfill that is not insulated from the ground and pollutes the groundwater and two sealed basins which are protected from seepage of leaches to the groundwater. The first of the lisymeter is supplied by distilled water simulating rainfall. The second one is supplied by leachates, what simulates the process of sprinkling the landfill with using leachates. There are about 210 liters of municipal waste in each lysimeter. Samples are collected on a monthly basis. The volume of supply reflects the average monthly precipitation. The purpose of the study is to investigate the dynamics of leaching that occurred at the initial stage of functioning of the storage site in Tychy Urbanowice when the groundwater environment was not protected. First analysis of leachates showed that electrical conductivity reached 32 mS / cm. The characteristic is high concentration of ammonium ion (1329 mg/dm^3), boron (6,860 mg/dm^3) and strontium (4,250 mg/dm^3). Concentrations of chlorides and sulphates reached 6.569 and 5118 g / dm^3, respectively. The results of the analyses were related to the results of chemical composition of groundwater taken from a piezometer situated on the dump and filtered below the waste and to the chemical composition of leachates from the drainage system of sealed sites of the landfill complex. The results obtained helped us to illustrate the degree of groundwater threat because of the deposited waste.

Code of abstract: T4.2.8
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Monitoring of chlorinated hydrocarbons found in groundwater at selected contaminated sites in Slovakia

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KEY WORDS - Monitoring, Contaminated Sites, Chlorinated Hydrocarbons, Slovakia

ABSTRACT

In the context of a comprehensive water protection in Slovakia (following the Water Framework Directive) it is necessary to address also point sources of pollution (so called contaminated sites). Within several projects related to monitoring of contaminated sites in Slovakia (managed by the State Geological Institute of Dionyz Stur), data on groundwater and surface water quality is collected and analysed since 2012. The paper's attention is focused on monitoring of chlorinated hydrocarbons found in groundwater within the Zlaté Moravce and Piestany cities as products of former industrial activities.

Former area of the Calex Zlaté Moravce factory (founded in 1949) has still a significant environmental impact. Mainly refrigerators and other refrigeration equipments were manufactured in the factory. Results of analytical determination of basic inorganic and especially selected organic indicators of chemical composition confirmed high concentrations of hazardous substances such as dichloroethylene (DCE), trichlorethylene (TCE), tetrachlorethylene (PCE) and vinyl chloride (VC) in groundwater. The contaminants are found in the wider area of the former Calex industrial park. Based on the results of several sampling campaigns we found that the contents of DCE, TCE, PCE and VC has fluctuating character in groundwater and with the distance from the main source area of contamination decrease.

In Piestany, contamination by aliphatic chlorinated hydrocarbons is caused by negligence in handling of hazardous substances and unsuitable storage and handling facilities (former Chirana and Tesla factories). Engineering production, dental equipments and manufacture of medical equipments dominated in the area. For the purpose of degreasing, especially 1,1,2-trichloroethene and 1,1,2,2 tetrachloroethene were rapidly used. Recent monitoring confirmed a large extent of contamination at the site, indicating exceeding the intervention values. Pollution by aliphatic chlorinated hydrocarbons was found south and southeast of the Chirana and Tesla area (areal extent of contamination reaches several km^2).

Code of abstract: T4.2.9
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Study on Naturally Occurring Radioactive Materials (N.O.R.Ms) in Groundwater of Two Islands with Various Geologic Settings in South Korea

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KEY WORDS groundwater, uranium, radon, gross alpha, geologic setting

ABSTRACT

In order to figure out the naturally occurring radioactive materials (N.O.R.Ms) such as uranium and radon in groundwaters from the G island in Incheon located in the western side and the J island in the southern part of South Korea, a total of 123 community water systems (CWSs) using groundwater as a resource of drinking water have been investigated for 9 years from 2007 to 2015.

In 71 CWSs of the G island, the maximum and minimum values of uranium concentrations were 72.21 μg/L and ND (not detected), respectively. The average and median values of uranium in the groundwater were 5.56 μg/L and 1.32 μg/L, respectively. The three CWSs (4.2 %) exceeded the maximum concentration level (MCL) of 30 μg/L for uranium, which is regulated by the national primary drinking water standard of United States Environmental Protection Agency (US EPA). The maximum and minimum values of radon activity were 614 Bq/L and 6 Bq/L, respectively. The average and median values of radon in the groundwater were 133 Bq/L and 111 Bq/L, respectively. 28 CWSs (39.4 %) did not meet the US EPA proposed alternative maximum concentration (AMCL) of 148 Bq/L for radon. The maximum and minimum values of gross alpha activities were 0.51 Bq/L and ND, respectively. The average and median values of gross alpha in groundwater were 0.07 Bq/L and 0.04 Bq/L, respectively. All gross alpha values meet the maximum concentration level (MCL) of 0.55 Bq/L, regulated by the US EPA's national primary drinking water standard. All CWS that did not meet the US EPA's MCL or AMCL have taken appropriate action, such as water treatment, alternative well development, mixing water of different origins, and so forth.

In the 52 CWSs of J island, the maximum and minimum values of uranium concentrations were 1.37 μg/L and ND (not detected), respectively. The average and median values of uranium in the groundwater were 0.15 μg/L and 0.07 μg/L, respectively. The maximum and minimum values of radon activities were 94.83 Bq/L and 0.07 Bq/L, respectively. The average and median values of radon in the groundwater were 23.74 Bq/L and 18.32 Bq/L, respectively. The maximum and minimum values of gross alpha activities were 0.24 Bq/L and ND, respectively. The average and median values of gross alpha in the groundwater were 0.03 Bq/L and 0.00 Bq/L, respectively. All values for uranium and gross alpha meet the maximum concentration levels (MCL) regulated by the US EPA drinking water standard of 30 μg/L and 0.55 Bq/L, respectively. All radon values do not exceed the US EPA proposed alternative maximum concentration level (AMCL) of 148 Bq/L.

The two islands have different geological settings where give the causes of the big difference in N.O.R.M. levels. Most of the G island is composed of Precambrian metamorphic rocks, Jurassic granite, Cretaceous granitoids, Cretaceous acidic dykes and Quaternary deposits. J island is a shield volcano, consisting mainly of basaltic lava flows and subordinate amount of pyroclastic and sedimentary rocks formed in Pleistocene Epoch, Quaternary Period, Cenozoic Era. The recharge and infiltration rate of precipitations in J island is much higher than that of G island, and the span of water cycle from recharge into aquifers to discharge from the aquifers in J island is much shorter than that in G island. Groundwater in aquifers of G island with long residence time has much higher N.O.R.M. levels than that of J island with relatively short residence time. This indicates that groundwater in metamorphic and granitic rocks with relatively long water-rock interaction times has a much higher level of uranium, radon, and gross alpha values than basaltic rocks with relatively short water-mineral interaction time.

There is little correlation between uranium and radon concentrations in goundwater in the G island. This relationships may be attributed to their unique physic-chemical characteristics such as half-lifes (^{238}U : 4.5 billion years, ^{222}Rn : 3.82 days), phases (^{238}U : dissolved ions, ^{222}Rn : inert gas), etc. Groundwaters discharged from Precambrian biotite gneiss, Jurassic biotite granite areas and Jurassic two-mica granite areas contain relatively high values of uranium concentrations (>30 μg/L). Groundwaters bearing relatively high levels of radon activities (>148 Bq/L) are dominantly found in the regions of Precambrian granitic gneiss. Groundwaters discharged from nine geologic settings that are Jurassic biotite granite, Precambrian biotite gneiss, Precambrian quartz schist, Precambrian mica schist, Precambrian biotite schist, unknown granite, Jurassic granite, Jurassic two-mica granite, Jurassic porphyritic biotite granite areas have also relatively high levels of radon activities (>148 Bq/L). No values of gross alpha exceed the MCL of US EPA. In J island, uranium and gross alpha values in groundwater are very low, however, radon values show their existence in groundwater system.

In order to figure out temporal variations of ^{238}U and ^{222}Rn concentrations in the G island, 8CWSs having 10wells named as GG, GK(1), GK(3), GY, GJ, GL(1), GL(2), GS, GD, GB were selected to monitor the N.O.R.M. levels once a month or once per two months from April 2009 to December 2015. The uranium concentrations at GL(2) containing the highest and the biggest fluctuation values among 10 wells had been changed over time ranging from 7.39 μg/L to 579.74 μg/L. The lowest and the smallest fluctuation of uranium concentration were detected at GL(1), GS and GG as ND and 3.50 μg/L ranging from 0.27 μg/L to 3.77 μg/L, respectively. The highest and the biggest fluctuation values of radon were detected at GL(2) with 1,711 Bq/L and 1,636 Bq/L ranging from 75 Bq/L to 1,711 Bq/L, respectively. The lowest and the smallest fluctuation height of radon values were detected at GK(1) and GS with 6 Bq/L and 100 Bq/L ranging from 20 Bq/L to 120 Bq/L, respectively. The highest and the biggest fluctuation values of gross alpha were detected at GB with 7.50 Bq/L and 7.50 Bq/L ranging from ND to 7.50 Bq/L, respectively. The lowest and the smallest fluctuation height of gross alpha values were detected at 10 wells and GY with ND and 0.12 Bq/L ranging from ND to 0.12 Bq/L, respectively. The temporal variations of N.O.R.M. concentrations in gourndwater could be caused by precipitation and/or surface water intrusions into the wells, groundwater mixing rate changes in a well and/or the wells related to different aquifers formed in various geologic settings, which could be main resources of the N.O.R.Ms, the lag time of the arrival time to the aquifers of interest, and so forth. Radon concentrations are related to the uranium concentrations in some groundwaters from the regions with the special geologic settings such as granitic rock or crystalline rock areas, etc.

Code of abstract: T4.2.10
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Test-site monitoring of groundwater and seismicity in Central Apennine (Italy) during 2016-17 earthquakes: pre- and post-mainshock aquifer responses

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KEY WORDS - earthquake hydrology, groundwater, water table, stable isotopes, trace metals

ABSTRACT
Since historic times, responses of aquifer systems to earthquakes, like increase of spring discharge, changes in river flow rate, and the sudden disappearance of springs or the generation of new ones, have been observed. The aim of this study was to identify potential patterns of level and composition changes before and after the seismic sequence recorded since August 2016 in Central Apennine.
The test-site Bussi sul Tirino monitoring area in Central Italy is located near the active normal faults of the Sulmona basin, along the southeast-ward prolongation of the faults that nucleated the L'Aquila 2009 Mw 6.3 event. In the site, seismic and GPS stations are acquiring data. Since July 2014, an experimental monitoring station is collecting data of piezometric level, electrical conductivity and temperature on a groundwater well 100 m deep, coupled with a time discrete sampling of the main springs for chemical and isotopic analyses. The recorded data have been subsequently filtered and correlated with the seismic events in a distance range of about 40 km from the monitoring well. The preliminary comparison shows statistically supported correlation between groundwater level changes and seismic activity. In detail, in several considered time slots, seismic events are preceded by a slight, but significant decrease of the water table and followed or accompanied by a strong increase of the water table itself in the monitoring well. The seismic sequence of 2016-17 in Central Italy affects the monitoring site showing a reversal trend respect with the seasonal water table depletion phase. In fact, as a result of main earthquakes, piezometric levels raised approximately of 30 cm in August, 20 cm in October and 80 cm in January, testifying the regional influence on groundwater flow caused by the seismic sequence. The results of chemical and isotopic analyses, repeated over time, highlight very steady characteristics due to the regional groundwater flowpaths, while trace metals content shows a very clearly different trend before and during the recent seismic sequences. Taking into account that the epicenters are located tens kilometers away from the study area, both water table and hydrochemical minor changes are in agreement with the theoretical previsions of seismic response for areas characterized by extensional tectonics.

Code of abstract: T4.2.11
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

The importance of groundwater monitoring for Cities – The example of Rome and its inhabitants involvement

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KEY WORDS - Urban Groundwater, Resilience, Climate Change, Groundwater Resources, Groundwater Pollution

ABSTRACT
Urbanization is a worldwide trend, with more than 50% of the world's population currently living in cities, reaching 70% in Europe. The urban water cycle is the key to integrated sustainable management for ensuring supply of safe (good quality) water, sanitation and correct drainage systems. Moreover, human activities such as land use change, extensive withdrawals and waste water discharge may exert a strong influence on hydrogeology, sometimes stronger than climate change, causing changes in the chemical–physical and quantitative status of surface and groundwater. As a consequence, urban water management poses not only scientific but also technical, socio-economic, cultural and ethical challenges.
Urban areas worldwide are employing different techniques for groundwater management. Hydrogeological monitoring are needed for a wide range of applications such as: protecting groundwater resources from deterioration; defining groundwater protection zones in newly urbanized contexts; assessing groundwater potential; identifying groundwater vulnerability; quantifying the recharge due to sewer and pipe leakage, furnishing the basic information for underground infrastructure design and to perform city-scale groundwater modeling and the historical evolution of urban groundwater systems.
In this context, monitoring groundwater and surface water resources represents a fundamental step for optimizing the urban water system and minimizing water consumption and deterioration.
In the city of Rome, most drinking water supplies derive from springs located far from the city, and is delivered to the population through the aqueduct network. Even if, currently, there are not specific issues related to water quantity, the Rome municipality is dealing with many groundwater-related problems. Some example are: pollution relationships between poor quality streams and aquifers, natural background levels of dissolved elements and compounds, differential settlements in stream valleys, subsidence and salinization as well as groundwater flooding.
The groundwater monitoring network of Rome constitutes a first important step for future development of surveys and research aimed at solving such problems. It has been established on 2014 using the wells owned by the government of Rome. As the network is not covering all the area of the Municipality of Rome, a specific form to involve citizens in the monitoring activities has been developed. Every citizen who has e private well, can share it with the government of Rome, participating to the network and contributing to the groundwater protection activities.
This involvement action will not only contribute to the monitoring network but also will increase the awareness of population in relation to environmental issues and natural resources protection.

Code of abstract: T4.2.12
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Trend analysis in agricultural groundwater: age dating, gas characterization and antibiotics

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KEY WORDS groundwater age dating, trends, N2-excess, nitrate, antibiotics

ABSTRACT
The application of manure and fertilizer in the sandy areas of the Netherlands strongly increased since the 1970s and subsequently decreased after the enactment of the Dutch Manure Law in 1986. The pulse in the leaching of fertilizers and manure that was the result, has affected the vulnerable groundwater in the permeable soils and subsurface of the Netherlands. We aimed to understand the relation between historic land use and measured concentrations of agriculture derived solutes in groundwater under intensive livestock farming by the systematic sampling of multi-level wells. We age dated large numbers of those wells using the tritium-helium method, and acquired field measurements of pH, EC, temperature, O_2 and total dissolved gas pressure (TDG), lab analyses of gas composition (N_2, CH_4), antibiotics and pesticides, thus complementing the multi-decadal time series of macro-chemistry. The $^3H/^3He$ ages were used to determine the "recharge year" which was defined as the sampling year minus the groundwater age in years. Trends for nitrate, sulfate, antibiotics and pesticides were analysed plotting the measured concentration versus recharge year and using statistical regression and smoothing techniques for quantification of the trends. Clear downward trends were found for nitrate, sulfate and total dissolved solutes, which coincide with the decrease of nutrient surpluses in farming since the reduction measures in 1986. Trend analysis for nitrate was strongly improved using the TDG as a proxy for the amount of N_2 produced during denitrification. Excess-N_2 was determined from the TDG measurements assuming that the increase in partial pressure relative to atmospheric equilibrium and excess air is completely determined by N_2 gas from denitrification. Evidence for the TDG – N_2 relation came from the measurements of gas composition and field TDG. This allowed us to use the sum of nitrate measured and N_2-excess as an indicator of the NO_3-loading during recharge, which clearly showed the trend reversal of NO_3 before and after the peak of 1985. The masking effect of denitrification was effectively removed using the N2-excess estimates. This study shows that a combination of age dating and proper field and lab measurements can reveal the temporal relations between historical inputs and the resulting groundwater pollution status.

Code of abstract: T4.2.13
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Use of a simple freeze-coring method to characterise riverbed – hyporheic zone heterogeneity

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KEY WORDS Freeze coring, riverbed, hyporheic zone, groundwater – surface-water interactions, monitoring

ABSTRACT

Characterisation of the heterogeneity, both physical property and contamination present, can be challenging in riverbed – hyporheic zone environments. This is because coring methods need to be mobile and as such are often simple manual methods as the use of drill rigs is not possible due to access constraints. Further, where riverbed sediments are larger grain – gravels, pebbles, cobbles and boulders etc. and heterogeneous, conventional coring methods typically struggle. Conventional coring may then veer away from these deposits that transmit the bulk of groundwater – surface water exchange flow and become biased towards the coring and sampling of finer grained sands and silts etc. that are easier to core. We propose instead a simple freeze coring method that is equally applicable to any of the above deposits. The coring process involves the manual hammering of a closed drive-point pipe to the desired depth in the riverbed which is then filled with liquid nitrogen causing the surrounding riverbed to freeze to the tube. The 'freeze core' is then winched free and comprises the riverbed sediments as a frozen lump around the drive-point pipe. This system may achieve excellent recovery of the riverbed including large pebbles and cobbles that would fail to enter or block conventional manual core tubes. Importantly, the core allows a visual inspection of the heterogeneous structure of the riverbed that is typically unseen by other methods. The coring process is illustrated through video material and the potential core sub-sample analysis that may be undertaken for core obtained on the urban River Tame system in Birmingham, UK. The methodology has applicability in many riverbed environments and is significantly underused by scientific and practitioner communities.

Code of abstract: T4.2.14
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Use of C, O/D, Sr and ^{3}H isotopes for determination of hydrogeochemical processes in Pliocene and Triassic aquifers of the Velenje coal basin, NE Slovenia

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KEY WORDS: hydrogeochemistry; C, O/D, Sr and 3H isotopes; groundwater; Velenje Basin; Slovenia

ABSTRACT

Velenje coal basin holds the only active coal mine in Slovenia, and is among the largest coal mine basins in central Europe. Large quantities of groundwater are being extracted to facilitate the mining and to lower the hydrostatic pressure. Three Pliocene clastic aquifers above the coal seam, and Triassic carbonate fractured aquifer below the coal seam were investigated in this study. The groundwater investigations have started intensively in the 1970's, and focused mainly on the hydrogeological research. During the 2014–2015 period, in the frame of a research project ARRS L1-5451, funded by Slovenian Research Agency, we have performed a comprehensive study of the groundwater geochemistry and isotopic composition. In total, thirty-eight samples of ground water were taken from the aquifers. A modified Solinst sampler was used to sample the wells to the depths of 400 m. Results show the Triassic aquifer to be dominated by HCO_3^-, Ca^{2+} and Mg^{2+} composition, with $\delta^{13}C_{DIC}$ values lying in the range from -19.3 to -2.8 ‰, originating from degradation of soil organic matter and dissolution of carbonates. Pliocene aquifers composed of clastic rocks have different composition than Triassic ones, with predominant Mg^{2+}, Na^{+}, Ca^{2+}, K^{+}, and Si and high alkalinity (up to 44.1 mM). $\delta^{13}C_{DIC}$ values range from -14.4 to +4.6‰. In Pliocene aquifers, methanogenesis is an important process in addition to both processes occurring in Triassic aquifer. PCA analysis (explaining 50% by the first axis and 19% by second axis) also clearly shows the differences among the aquifers. Waters are mostly oversaturated with respect to calcite and dolomite, and as a consequence of methanogenesis, dissolved oxygen values are much lower in the Pliocene aquifers (10–30%) compared to the Triassic ones (60–80%). In addition, a new approach with strontium isotopes shows $^{87}Sr/^{86}Sr$ values ranging from 0.70820 to 0.71056 in Pliocene aquifers and from 0.70808 to 0.70910 in Triassic aquifers, with carbonate dissolution present in all aquifers, and additional silicate dissolution in the Pliocene aquifers. $\delta^{18}O$ and δD indicate that groundwater is of a meteoric origin, and ^{3}H tracer reveals that groundwater is generally older than 40 years. Investigations are planned to continue the geochemical analyses of the shallow aquifers (Q and Pl) and gases in the groundwater.

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Using Cl/Br ratios and water isotopes to trace aquifer recharge in a highly irrigated area, the Po Plain (N Italy)

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KEY WORDS: Groundwater monitoring, water use, water quality, nitrate, arsenic

ABSTRACT
Aquifer recharge of irrigation water may affect the quality and quantity of groundwater. Here, Cl/Br ratios, water isotopes, and other hydrochemical tracers are used to quantify the effects of irrigation on an aquifer system in the Oglio River basin (Po Plain, N Italy). The area hosts a mono-layer aquifer of sands with an oxidized *hydrofacies* in its northern part (higher plain) that passes southwards into a multi-layer aquifer (lower plain) with an increasing proportion of silts and clays and a reduced *hydrofacies*. Irrigation in the higher plain is fed mainly by Oglio River water and distributed through a channel network, whereas groundwater is the main source of irrigation water in the lower plain. Hydraulic head monitoring showed that, in the irrigation period, the water table rose up to ≈ 6 m in the higher plain and decreased up to ≈ 1 m in the lower plain.

For the aquifer beneath the higher plain, end-member mixing models of Cl/Br and $\delta^{18}O$ in water showed that it is recharged by a mixture of local precipitation and irrigation water sourced by Oglio River. The proportion of groundwater derived from irrigation ranged mostly between 60 and 85%, with groundwater from a few wells showing only 20 to 30% contribution from this source. Concentration of NO_3 vary inversely with the proportion of irrigation water, which contains little NO_3. Where groundwaters contain a low proportion of irrigation water, concentrations of NO_3 are > 50 mg/L NO_3 and exceed regulatory limits.

For the aquifers beneath the lower plain, our tracers suggest that some wells are likely recharged by surface waters whereas others, mostly deep aquifers, receive little or no recharge by surface water and/or local precipitation. The huge amount of groundwater abstracted in the irrigation period may have implications on groundwater As, concentrations of which exceed the WHO limit of 10 µg/L in many groundwaters from the lower plain. The effect of abstraction for irrigation should be quantified through a comprehensive monitoring strategy.
This work was supported by Fondazione Cariplo, grant 2014-1282.

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Wavelet-based multivariate time-series analysis of CO_2 flux at soil-atmosphere boundary, with respect to hydro-meteorological factors: Results from a baseline survey at an artificial CO_2 leakage experimental site in South Korea

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KEY WORDS concentration and flux of CO_2, soil-atmosphere boundary, carbon storage, wavelet analysis, multivariate time series

ABSTRACT
Careful monitoring and interpretation of CO_2 gas concentration and flux at soil-atmosphere boundary is a crucial task for successful and secure geologic carbon storage. However, it is difficult to differentiate the leakage of stored anthropogenic CO_2 from the signal of natural CO_2 because the concentration and flux of soil CO_2 are strongly fluctuated with time and space and are significantly controlled by hydro-meteorological factors. To establish the scheme of soil CO_2 gas monitoring, Korea CO_2 Storage Environmental Monitoring (K-COSEM) Research Center is operating a CO_2 Environmental Impact Test (EIT) site where artificial CO_2 release tests are conducting. To evaluate real-time monitored soil CO_2 data as a function of hydro-meteorological factors, nonstationary multivariate time-series data of hydrological variables such as precipitation, air temperature, soil temperature, soil moisture, and soil EC were collected by automatic chambers, eddy covariance tower, and TDR sensors. Wavelet analysis (WA) were used to decompose the signal into the successive time-frequency scale to identify short- to long-scale periodic phenomena. Then, we attempted to characterize spatio-temporal dynamics of soil CO_2 as a function of hydro-meteorological driving forces in various time-frequency scales. The high variability of CO_2 concentration data could be decomposed into the annual trend, seasonal cycle, and daily oscillation with an irregular noise pattern. The annual/seasonal variability is mainly caused by the CO_2 uptake by vegetation during the growing season, while the daily and irregular oscillations are mainly due to the change of horizontal advection and vertical mixing of CO_2 as a result of the change of metrological conditions (temperature, wind speed, barometric pressure, and humidity) at the soil-atmosphere boundary. From the wavelet coherence analysis, we could explain the lead/delay characteristics and phase differences between the highest correlated wavelet component of hydrological variables and CO_2 concentration. Finally, we estimated the relative contribution of various hydrological factors to the observed CO_2 dynamics. The wavelet-based multivariate time-series approach in this study can be useful to better evaluate the hydro-meteorological factors controlling complex physical, chemical, and biological interactions between soil and air systems.
This study was supported by the Korea Ministry of Environment (MOE) as "Korea-CO_2 Storage Environmental Management (K-COSEM) Research Program".

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Multi-element isotopic fingerprinting on aqueous-phase chloroethenes derived from chlorinated pitches

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KEY WORDS - CSIA, chlorinated pitches, contamination liability, Ferrara, Bussi

ABSTRACT
Compound Specific Isotope Analysis (CSIA) is an effective tool in order to apportion the source of groundwater contamination. Isotopic signature may reflect the production process of a compound or the origin of raw materials used in the production. Nijenhuis et al. (2013) demonstrated that PCE and TCE, as by-products of the distillation of chloromethanes via thermal chlorination, show strongly depleted $\delta^{13}C$, with values ranging between -87 and -65‰ for PCE and between -79 and -64‰ for TCE. This finding was related to a field study in Northern Italy (Ferrara). In order to strengthen the investigation tool, the presented study involves a multi-element and multi-site approach by taking into account the same industrial process of chloromethanes production and nearby dumping in different sites (in charge of different producers and in different hydrogeological settings). In particular, the $\delta^{13}C$, $\delta^{37}Cl$ and $\delta^{2}H$ were analyzed in the molecules of PCE, TCE and 1,2 DCE dissolved in groundwater at two distinct locations in Italy. The existing fingerprinting of $\delta^{13}C$ in Ferrara site was complemented by $\delta^{37}Cl$ and $\delta^{2}H$ analyzed in some selected boreholes from the previous survey. The second investigated site is known as the Bussi site (Central Italy). Contaminated groundwater was sampled at the two sites in two distinct sampling rounds, for a total of 30 boreholes (the second sampling round is being performed in 2017). The geological settings are different at the two sites: a large alluvial plain (Ferrara site) and a narrow valley with macroclastic alluvial deposits and travertines (Bussi site).
The following issues will be targeted during the presentation: can we apply the CSIA approaches for source apportionment in different hydrogeological settings with different potential producers of chlorinated aliphatic hydrocarbons (CAH)? Is it feasible to define a multi element fingerprinting for CAH derived from chlorinated pitches, and how does the fractionation of the different stable isotopes respond to production, dumping and biodegradation?
The research will show that the multi-isotope approach can help addressing liability of contamination events in urban and periurban areas, where the pattern of contaminant distribution and concentration in groundwater does not allow identification of the polluter.

References. Nijenhuis, I., Schmidt, M., Pellegati, E., Paramatti, E., Richnow, H.H., Gargini, A. 2013. A stable isotope approach for source apportionment of chlorinated ethenes plumes at a complex multi-contamination events urban site. Journal of Contaminant Hydrology, 153, 92–105.

Code of abstract: T4.2.18
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Real time karst spring monitoring: first results about the groundwater circulation in the karst aquifer feeding Pertuso Spring

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KEY WORDS groundwater, karst spring, circulation, real time monitoring, time series data

ABSTRACT

In karst groundwater monitoring, springs are preferential measuring points even if, due to the high heterogeneity of the rock matrix, large voids and high flow velocities, the interpretation of time series data could be uncertainly. As a matter of fact, the assumptions made for monitoring groundwater flow in porous aquifer are not valid in karst terrains.

This paper deals with the Environmental Monitoring Plan concerning the catchment work project of the Pertuso karst spring, which is going to be exploited to supply an important drinking water network in the South part of Roma district. The Pertuso Spring, located in the Upper Valley of the Aniene River, is the main outlet of a large karst aquifer which is one of the most important water resource in the southeast part of Latium Region, Central Italy, used for drinking, agriculture and hydroelectric supplies.

The monitoring program initiated in 2014 to monitor background chemical status of groundwater coming from the Pertuso Spring, as well as to obtain information about the functioning of the Cretaceous limestone aquifer feeding the spring.

Since 2014, in situ measurements of pH, groundwater level, temperature, electric conductivity, redox and dissolved oxygen of water have been carried on at Pertuso Spring, using a multiparametric probe which directly interfaces with a data logger for real-time recording of hourly data.

The objective of this ongoing monitoring is to discriminate anthropogenic impacts from natural variations, at both short- and long-term scales, providing data about the basic outline of the groundwater circulation.

PH, redox and dissolved oxygen data are useful to better understanding the natural dynamics of the karst system and to evaluate the early detection of anthropogenic deviations. Electrical conductivity and temperature data came out to be useful in the assessment of regional hydro-climatic trends. In particular, in the study, variations in groundwater temperature and electrical conductivity before, during, and after several large storms allowed to distinguish a conduit-flow aquifer system from a diffuse-flow one.

Code of abstract: T4.2.19
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Estimating groundwater mixing ratios using hydrogeochemistry parameters and nitrate isotopes due to excessive groundwater pumping in the Bandung basin, Indonesia

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KEY WORDS - excessive groundwater pumping; groundwater mixing; mixing ratio; nitrate isotopes; Bandung basin, Indonesia

ABSTRACT
One crucial task in groundwater research and management is estimating groundwater mixing ratios. In this paper, we present estimates of mixing ratios for shallow and deep groundwater in an area of excessive groundwater pumping; three depression areas with different magnitudes of groundwater drawdown were analyzed. We estimated the mixing ratio using two methods: (1) the total mixing ratio using all parameters, and (2) the mixing ratio using nitrate concentration. The values for the total mixing ratio indicate that mixing between the shallow and the deep groundwater clearly occurs in all three depression areas, but with different ratios. The area with the largest drawdown had the largest mean mixing ratio (0,42). The spatial distribution map of the total mixing ratio clearly shows that the biggest mixing ratio occurs near the center of the cone of depression, and that the ratio decreases gradually away from the center of the depression area. There was a good correlation among total mixing ratios, CFC-12 concentrations, and modeled vertical flux. Similarly, there was a good correlation between mixing ratios using all the parameters and mixing ratios using only nitrate concentrations as a contaminant tracer. Both the total mixing ratio and the nitrate mixing ratio had a positive tendency with CFC-12 concentration. This result shows that nitrate is an effective contaminant tracer in the study area. Overall, this study concluded that the estimation of mixing ratios provides effective results that are consistent with the results from other methods. This study provides further proof that groundwater mixing between the shallow and deep groundwater has clearly occurred in the Bandung basin as a result of excessive pumping.

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Hydrochemical characteristics of the groundwaters in Prilep's part of Pelagonia valley– Republic of Macedonia

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KEY WORDS - groundwater, Piper diagram, Chadha's diagram, cations, anions.

ABSTRACT
Hydrochemical properties of the groundwaters in Prilep region within the Pelagonia valley are analyzed with 12 samples of groundwater, taken from wells that exploits. The sampling was made only once on 27.08.2013. The groundwaters are used by the locals of this region as technical water, for irrigation of the surrounding arable land and for industrial needs.
Wells of were taken samples of groundwater is separated into three groups: wells with free level with depth up to 10 m, wells with free level with depth up to 100 m and artesian wells. The graphical methods, Piper diagram and Chadha's diagram, were applied in order to determine the hydrochemical properties of the groundwater. The results indicate that the groundwater samples have different hydrochemical properties. $Ca^{2+} > Na^{+} > Mg^{2+}$ for the cations and $HCO_3^- > Cl^- > SO_4^{2-}$ for the anions were dominantly dissolved ions in the majority of the water samples. Generally, increased values of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, $HCO3^-$, K^{+} and Cl^- occur in the groundwater from deeper artesian wells, as a result of the longer retention time of water in the underground and its interaction with the geological environment.
Dominant groundwater in Prilep field, in all three types of wells, are waters from hydrocarbonate class ($HCO3^-$), calcium group (Ca), the first type of water.
Groundwater from the shallow wells show the increasing content of K^{+}, NO_3^- and PO_4^{3-} which indicates water pollution from fertilization of the cultivated areas, livestock farms as well as communal wastewater.

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Study on Carbon sequestration flux and its annual dynamic variation in watershed systems of Yangtze River, Yellow River and Pearl River, China

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KEY WORDS carbon sequestration; global change; Yangtze River/Yellow River/Pearl River, China

ABSTRACT

Objective: Continual locating monitoring have put into effect at the controlling hydrological sections on Yangtze River, Yellow River and Pearl River respectively during 2011 to 2012. The purposes are to calculate the annual DIC flux formed by geological processes on the controlling sections and to make estimation calculation of annual amount CO_2 absorbing from atmosphere through geological processes.

Methodology: The monitoring items include as following, discharge, HCO_3^-, Ca^{2+}, pH, EC, DOC, rainfall, water temperature and so on. Analyzed hydrochemical indexes include K^+, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, SiO_2 etc.

Original data and results: The output flux of DIC in Pearl River and Yellow River watershed is 5.34×10^6 tCO_2/a and 20.69×10^6 tCO_2/a respectively, the carbon sequestration intensity is 16.34 $tCO_2/km^2.a$ and 27.10 $tCO_2/km^2.a$ in 2011. Similar results in Pearl River and Yangtze River watershed in 2012 are calculated as following, the output flux of DIC is 7.18×10^6 tCO_2/a and 43.81×10^6 tCO_2/a respective, the carbon sequestration intensity is 21.96 $tCO_2/km^2.a$ and 25.69 $tCO_2/km^2.a$. The DOC concentration of Pearl River, Yangtze River and Yellow River water is 2mg/l, 4mg/l and 6~8mg/l respectively.

Conclusion: (1) The hydrochemical components of river water are mainly formed by rock weathering processes. The discharge is the main control factor of carbon sequestration flux. (2)The monitoring sections of three watersheds control an area of 2.78×10^6 square km, the output DIC is about 70.00×10^6 tCO_2 in total. The DOC concentration of Pearl River, Yangtze River and Yellow River water is 2mg/l, 4mg/l and 6~8mg/l respectively. Therefore, the annual output carbon sequestration flux should be greater than 91.88×10^6 tCO_2 during 2012. This value will be a little difference during the years. (3)Thus shows that the carbon sequestration effect formed by geological processes in a global scale is a considerable sum.

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Characterization of the Groundwater Quality in a Poultry Production Area

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KEY WORDS - nitrate, groundwater pollution, poultry production, hydrochemistry, groundwater quality management

ABSTRACT
The poultry industry is the main economic activity of the Bastos municipality, the largest egg producer in Brazil, equivalent to 14.4 million eggs/day. The city with an approximated area of 170.912 km^2, has much more laying hens - almost 20 milion, than habitants (estimated 21.070). This activity is responsible for the production of large volumes of waste, which disposed improperly, could constitute a potential source of groundwater contamination of the Bauru Aquifer System (SAB), the main source of regional public water supply and of the proper poultry industry.
NO3-N concentrations up to 51,2 mg/L, above the potability limit (10 mg/L), were found in supply wells of the Bastos' rural area and a hydrochemical monitoring, objective of this study, was performed to characterize SAB´s quality problems and to investigate its relation with the poultry industry and another potential agricultural sources of nitrate pollution.
The activities developed consisted by the preparation of a database and map of the 216 regulated supply wells with well log, chemical analysis and land use information, as well as the statistical treatment of these data; groundwater sampling of selected 30 wells in two campaigns along a hydrologic year for physicochemical and chemical parameters; consolidation and interpretation of data.
The first results showed that the SAB in the area is composed by the sandstones of the unconfined Adamantina Aquifer with 80 - 150 m thickness, followed by the siltstones of the Araçatuba Aquitard with thickness between 13 and 34 m, covering the basalt unit (fractured Serra Geral Aquifer). Most of the private wells are pumping just the first aquifer, while the 04 public wells are pumping both Adamantina and Serra Geral. The recharge occurs in the whole area, except where the surface is impermeable. The potentiometric maps indicate groundwater flow from the two water divisors located at NE and W, downward to the main drainages. The hydrochemical results showed that there is anthropic impact in the natural groundwater chemistry. The natural composition of the Adamantina Aquifer is mainly K-Na-HCO3 type, while the contaminated water is Mg-Ca-NO3 type, showing that it will be necessary to manage very well the groundwater resources in the area, as its quality is becoming close to be improper for the poultry consumption.

Code of abstract: T4.2.23
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Contamination of urban snow in the area of Faculty of Earth Sciences – Sosnowiec, Poland.

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KEY WORDS snow, smog, contamination, metals, PAH

ABSTRACT

Poland experienced significant problems with air quality this winter. High concentrations of airborne particulate matter of the winter smog type were noticed periodically. This situation could cause precipitation contamination, which may result in surface water and groundwater pollution. Taking into account this problem the investigations of the snow quality in the area of Faculty of Earth Sciences, University of Silesia in Sosnowiec were carried out. The Faculty is situated in the urbanized and industrialized area of Upper Silesia where the concentration of dust (PM10) in the air before snow sampling reached periodically up to 297µg m^{-3}. Snow samples were collected from 2 sites located at the roofs of Faculty buildings, one at the top of main Faculty building 80 m high, and one at the top of lower attached building, 15 m high, and 2 sites at the ground surface (one near the car parking lot and one at the faculty weather station area). From each sites two samples were taken: one from the top of the snow layer (fresh snow from the first snowing event after smog occurrence) and one from the bottom snow layer (older snow).

Melted snow samples were slightly acidic (pH from 4.13 to 5.35) and contained significant amounts of metals (Hg up to 2.18 □g dm^{-3}, Pb up to 159 □g dm^{-3}, Ni- up to 24.4 □g dm^{-3} and Zn up to 19.459 mg dm^{-3}). Low concentrations of Cr (up to 8.7□□g dm^{-3}), Cu (up to 27.3 □g dm^{-3}) and Cd (below detection limit) have been noticed. Concentrations of Hg and Pb exceeded drinking water standards more than 2-fold and 15-fold, respectively.

Snow samples contained also elevated concentrations of polycyclic aromatic hydrocarbons (PAHs). Concentrations of benzo[a]pyrene reached 0.034 □g dm^{-3} and the sum of measured 16 PAHs reached 3.9595 □g dm^{-3}.

A sum of concentrations of the specified 4 compounds [benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene] included in the EU and Polish drinking water regulations reached 0.127 □g dm^{-3}, exceeding the mentioned standards.

Significant spatial differentiation of snow contamination has been noticed. In all 4 sites fresh snow was more acidic . Higher concentrations of Hg and Pb were noticed in the fresh snow at the ground and in the old snow at the roofs. The highest concentrations of benzo[a]pyrene were measured in the old snow at the roof of the lower building and at the ground in the area of car parking lot.

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Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Detection of diesel release into soil using hydraulic control system with resistivity sensor

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KEY WORDS oil release; detection; soil; resistivity sensor; hydraulic control system

ABSTRACT
A new apparatus for the detection of oil release in soil was developed using hydraulic control system with soil resistivity sensor. The hydraulic control system was composed of a sand-filled cylinder, electrolyte, and drainage tube, and time domain reflectometry (TDR) was used as the soil resistivity sensor. In this study, the applicability of the new apparatus was discussed by conducting diesel release detection tests in a sandy soil. During the diesel release, the inflow of diesel in the cylinder increased the hydraulic pressure, and internal solution was expelled through the drainage tube when hydraulic pressure surpassed a given level. Since an electrolyte solution with a low resistivity was placed at the bottom of the cylinder, resistivity increased sharply with the drainage. Changes in soil resistivity are useful as an indicator of oil release. Since the sensitivity of oil release detection was dependent on the configuration of the hydraulic control system, the preferential configuration was chosen by conducting release detection tests under different component configurations. Results indicate that the hydraulic control system equipped with a resistivity sensor is applicable to detect oil release from USTs in soil.

Code of abstract: T4.2.25
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Fate of antibiotics in the soil-groundwater system in sewage irrigation area

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KEY WORDS Fate, Antibiotics, Soil-groundwater system, Sewage irrigation area

ABSTRACT

Sewage irrigation can deal with the problem of water shortage, however it may introduce lots of contaminant such as antibiotics into the soil-groundwater system. To study the fate of antibiotics in the soil-groundwater system, a typical sewage irrigation area, Xiaodian Sewage Irrigation Area, was choiced as study area. 14 surface water, 9 groundwater, 2 profiles and 3 boreholes were sampled and 4 categories of antibiotics (Macrolides (MLs), Fluoroquinolones (FQs), Tetracyclines (TCs) and Sulfonamides (SMs)) were analysed by HPLC-MS/MS.

The results showed that all the 25 kinds of antibiotics were detected in the surface water while 15 kinds were detected in the groundwater. MLs and FQs were the main antibiotics detected in the shallow vadose zone. The contents of antibiotics in the profile GS-1 – GS-4 were 2-3 times as those in groundwater irrigation area, indicating that sewage irrigation has a significant impact on the contents of antibiotics in the soil.

The contents of antibiotics in both GS-1 – GS-4 and GS-5 exceeded MCL of 100 ng/g. The elevation of their contents in the wet season could be related to that of water level. The highest content of antibiotics occurring at the top left corner is at the same elevation as the sewage in the Beizhang Drainage Canal at wet season. The distribution of antibiotics was influenced by the irrigation flow direction. Approximately 50% and 70% of the FQs was reduced at the upper 50 cm and 80 cm depth, respectively. TCs may have experienced significant lateral migration. MLs and SMs has a similar distribution on the profile. The decrease of their contents occurred in the upper 20 cm.

22 and 20 kinds of 25 antibiotics were detected respectively in the sediment core of sewage irrigation area and groundwater irrigation area. The order of contents of 4 categories of antibiotics in both cores was: FQs > TCs > SMs > MLs. The sewage irrigation influenced the distribution of antibiotics in the sediment core. FQs was the predominant contaminant with the highest average content (264.29 ng/g). The sewage which was used for irrigation both enhanced the amount of antibiotics and took a role of medium in the antibiotics migration.

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Groundwater monitoring in vicinity of roads

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KEY WORDS - groundwater monitoring, roads, roads pollution

ABSTRACT
Roads for motor vehicles provide a linear source of environmental pollution, including also the groundwater environment. The influence on the environment depends on the road class, the traffic intensity and the accompanying infrastructure. Groundwater vulnerability which determines the real level of threat to groundwater is a very important factor. The environmental threat is enhanced during the construction phase of new road projects. Road investments are intensively developing in the countries of Central and Eastern Europe, including Poland. 2350 km of new expressways and highways have been built in the period of 2005-2016 in Poland. According to the data taken from the General Directorate for National Roads and Motorways in Poland in 2010, more than 12,000 km of national roads cross the area of Main Groundwater Reservoirs (MGR) and almost 3,400 km passed through the area of low insulation level of groundwater. According to the plans from 2010, the length of national roads colliding with the MGR was supposed to increase by 4,200 km and next 1270 km was supposed to cross the MGR areas characterized by a low level of insulation. Taking into account both facts one shall assume that currently over 4,500 km of the main roads cross the MGR areas of low insulation. This represents about 24% of the main national road network. In spite of this, groundwater monitoring is carried out in the vicinity of a small number of road investments. Typical impurities in the outflow from roads are: organic pollutants (hydrocarbons), heavy metals, chlorides (NaCl and $CaCl_2$) and suspension which poses a risk of surface water.
The paper presents an overview of the results of several years long of groundwater monitoring in the vicinity of 3 road investments. The analysis includes: composition of chemical waters, geological structure, hydrogeological conditions and spatial development. Groundwater monitoring results from the pre-investment stage, from construction stage and from operation phase were taken into account. An important element of the analyses was the assessment of the groundwater vulnerability. The results of groundwater monitoring confirm the impact of the analyzed investments on groundwater. This concerns mainly chlorides and petroleum substances. For example, the concentration of chlorides increased from 21 mg/dm^3 in the period preceding the investment in 2005 to 490 mg/dm^3 in 2013 in water taken from a one piezometer situated along the Wojnicz by-pass (southern Poland).

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Hydrogeochemical charactaristics of groundwater quality in Shimabara, Nagasaki, Japan

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KEY WORDS - Hydrogeochemical processes, Gibbs diagram, Durov diagram, Chloro-alkaline indicies, Cluster analysis

ABSTRACT

Hydrogeochemical processes were investigated based on groundwater chemistry data to evaluate how the groundwater status relates to geological factors in Shimabara, Nagasaki, Japan. Groundwater is extracted in this area for municipal use, including drinking water. Groundwater samples were collected at 29 locations, from resident wells, municipal wells, and springs between May and December, 2015. Some municipal wells have been polluted by nitrate and therefore the city has developed several new wells. The sampling area was divided into three parts according to land use and elevation: forest (>300 m), upland field (<300 m), and urban area (<100 m). Hydrogeochemical processes were studied using standard approaches such as various ionic ratios, Durov diagrams, Gibbs diagrams, and chloroalkaline indices using ionic concentration and total dissolved solids. According to the Gibbs diagram, the ionic compositions of groundwater in forest depends on precipitation, and those in upland and urban areas are determined by water–rock interactions. The total cation (TZ^+)-based ratios (TZ^+)/(Na^++K^+) and (TZ^+)/(Ca^{2+}+Mg^{2+}), and the Ca^{2+}/Mg^{2+} ratios indicated that silicate, calcite, and dolomite dissolution are more dominant than alkali feldspar for mineral dissolution. In addition, chloro-alkaline indices and the Na^+/Cl^- ratio showed that cation exchange plays an important role across the study region, controlling the concentrations of major dissolved cations (Na^+, K^+, Mg^{2+}, Ca^{2+}). At most sampling sites, ion exchange occurred between Mg^{2+} and Ca^{2+} in the liquid phase and Na^+ and K^+ in the solid phase, considering inputs from anthropogenic activities such as upland cropping and livestock farming. Mineral dissolution and ion exchange corresponded to the result of the Durov diagram; concentrations of Mg^{2+} and Ca^{2+} increased due to dissolution of silicate, calcite and dolomite. In contrast, ion exchange reduced Mg^{2+} and Ca^{2+}. Alkali feldspar and ion exchange were identified as responsible for elevation of Na^+ and K^+ concentrations. Understanding hydrogeochemical processes helps to assess factors related to water–rock interaction and anthropogenic effects that can change water chemistry. The results are important to develop further water resources in future.

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Identification of nitrate origin in groundwater by measurements of $\delta^{15}N$ and $\delta^{18}O$ and N_2 excess.

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KEY WORDS - nitrate, groundwater, isotopes,

ABSTRACT

The threat of nitrate pollution of groundwater becomes a growing problem globally. Proper identification of the sources of pollution allows to take appropriate measures to protect groundwater systems. Measurements of $\delta^{15}N$ and $\delta^{18}O$ in nitrate can identify the processes such as nitrification and denitrification but do not give exact answer about sources of nitrate in aquifers. Measurements of excess of nitrogen dissolved in water, assuming that it comes from the denitrification of nitrates, can give information about initial concentration of NO_3^- in the system. Combining information about the excess of nitrogen and the isotopic signature of nitrate can identify sources of nitrate in groundwater and the presence of denitrification. This knowledge is important for management of groundwater resources.
The present work demonstrates use of isotopic fingerprinting of NO_3^- together with N_2 excess for identification of nitrates sources and quantification of the extent of denitrification in porous-fissured karstic aquifer near Czestochowa (southern Poland) threatened by nitrate pollution from agricultural sources and from domestic sewage and wastewater.

Acknowledgements.
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Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Irrigation Water Quality in Kopruoren Basin, Kutahya, Turkey

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KEY WORDS - irrigation water quality, trace metals, Kopruoren Basin, Turkey

ABSTRACT

In this study, physico-chemical properties and major ion chemistry of 19 groundwater samples were used to evaluate irrigation water quality in Kopruoren Basin. Kopruoren Basin is located north of Kutahya city in Inner West Anatolia. The total drainage area of the basin is around 320 km^2. The geologic units outcropping in the study area are Paleozoic metamorphic rocks, Permian-Triassic marbles, Neogene sedimentary and volcanic rocks and Quaternary deposits. Previous geological and geophysical studies revealed out that the water bearing units are the limestones and tuffs in Neogene series and they form a confined aquifer system. The agricultural products of the basin are mostly bread and durum wheat, barley, sugar beets and corn. Crop irrigation water requirement for sugar beets is relatively high and the amount of precipitation received in the area is not enough for sugar beets to grow therefore irrigation is necessary. Irrigation season in the area usually starts in late May and continues until mid-October depending on the amount of precipitation received. To determine the irrigation water quality in the basin, water sampling was carried out in July and October 2011 during two field trips and 19 samples were collected from irrigation wells located in 10 different villages. According to the results, the groundwater resources of Kopruoren Basin have low sodium hazard however they are very hard in nature due to the dominant presence of Ca^{+2}, Mg^{+2} and HCO_3^- ions. In general, samples are suitable for irrigation according to various indices like sodium adsorption ratio, permeability index, magnesium ratio and potential salinity. The presence of nitrate in two samples is alarming since sensitive crops can accumulate high levels of nitrate. One of the samples contains more than 1000 µg/l boron, which can be toxic to sensitive crops. All of the samples contain As, in concentrations varying between 2.6- 62.3 µg/l. As concentrations in 79% of the samples exceed the WHO drinking-water guideline of 10 µg/l. There are no guidelines regarding As concentrations in irrigation water in Turkey however according to the Canadian Council of Ministers of the Environment guidelines As concentrations in all of the water samples are below the recommended concentration (100 µg/l).

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Monitoring long-term effects of land-use change and groundwater abstraction on a Zambian karst aquifer system

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KEY WORDS Monitoring concept, anthropological impact, Northern Zambia, irrigation

ABSTRACT

Determining the hydrogeological impacts of anthropologically induced land-use changes is a task often assigned to modelling. However investigations based on actual measurements are rare, especially on a decadal or centennial time scale and in a data-scarce country like Zambia. The Mpongwe/Munkumpu karst area is located in the Copperbelt Province in Northern Zambia and consists mainly of calcareous-dolomitic rock of the Ipumbu Formation. Providing fertile soils, it is the most important agricultural production area in the Copperbelt and among the most productive areas in Zambia. While high amounts of rainfall (around 1,150 mm/a) sustain the crops' water needs during the rainy season from November to April, agricultural production completely relies on huge center pivot irrigation schemes for the rest of the year, covering more than 4,200 hectares of land. Water for irrigation is drawn, to great extent, either directly from the groundwater bodies or indirectly from sink holes. Development of the farming complex started in the 1970s, not long before a feasibility study of the German Federal Institute for Geosciences and Natural Resources (BGR) was conducted in 1974. Based on groundwater level measurements, basic hydrochemical analysis and discharge measurements at streams, the study described the near-natural hydrogeological and hydrological baseline conditions of the formerly open, summer-green forest, offering a rare possibility to determine effects of land-use change on groundwater quality, quantity and baseflow. For this purpose, a monitoring concept was developed, including a campaign aiming at reproducing the measurements done in 1974 under current-day conditions, to enable a direct comparison of the hydrogeological conditions. Furthermore, the original water budgeting approach will be supplemented by use of stable isotopes investigations to estimate return flows from irrigation. The investigations will provide valuable information for Zambian authorities, which currently aim at setting up country-wide water balances to evaluate agricultural potential and to implement a catchment-based water resources planning prescribed by the new water legislation.

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Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Volume estimation of free LNAPL in groundwater: comparison of Pancake Model and Vertical Equilibrium Model results and identification of critical points

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KEY WORDS - LNAPL, free phase, volume estimation, Pancake Model, Vertical Equilibrium Model

ABSTRACT

LNAPLs (light non aqueous phase liquids) are potential long-term sources of contamination and are the most common and harmful contaminants in groundwater. In the subsoil, 99% of LNAPL is presented as free and residual phases, so it is fundamental estimate the volume of free phase through the application of two different conceptual models: Pancake Model (PM) and Vertical Equilibrium Model (VEM).
According to the PM, the LNAPL creates a buoyant pool with uniform and constant saturation on the water table and the thickness measured in the monitoring well is an apparent thickness, which must be correct through the exaggeration factor deduced by baildown tests, in order to obtain the real thickness.
The VEM instead, assumes that the LNAPL can penetrate below the water table and the pore fraction occupied by LNAPL is less than 100% due to the presence of air and water, and its saturation varies with the depth. The saturation profiles can be obtained with software as LDRM (distributed by API) which requires information about the features of the LNAPL and the affected aquifer.
The two models are been used, together with Thiessen polygons and at grid at regular square mesh (100 x 100 m and 200 x 200 m), to estimate the volume of the free phase existing in an Italian contaminated site. The volume estimation has been carried out considering the type of free product detected (diesel, gasoline and mixtures of gasoline and diesel) and its features, the type of soil and relative effective porosity. The comparison between the results obtained using the two models and different methods to calculate areas, shows that there is a difference of thousands of cubic meter between the estimated volumes. In particular, the VEM estimates lower volumes than the PM probably due to the LNAPL saturation considered in the two models (100% in PM and less of 100% in VEM). In addition, it was found that for both models the estimated volume vary with the different types of area suggesting that the area delimitation is a critical point, which influences the estimation. Other critical points in the volume estimation are the presence of different types of LNAPL and the lack of some site-specific data among which the porosity whose sensitivity analysis has revealed that its reduction provides a reduction of about 20% of estimated volume.

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Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Nitrates migration in the regional groundwater recharge zone (Lwówek region, Poland)

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KEY WORDS: groundwater contamination, nitrates, groundwater flow condition

ABSTRACT

The regional groundwater recharge zones are sensitive for contamination because high downward gradients enable contaminants to migrate downward to a deep parts of the flow system. In the regional recharge zones of Quaternary aquifers located in central Wielkopolska (Lwówek region, Poland) relative high nitrates concentration (>15 mgNO_3/l) was detected at a great depth (>80m). It is a region dominated by agriculture where sands and gravels in the whole geological profiles occur locally. These conditions facilitates contamination of groundwater by nitrates. The research performed in the net of multilevel piezometers shows that in shallow part of the aquifer the concentration of nitrates exceed 30 mgNO_3/l. In the deep part of the flow system relative high nitrates concentrations were documented in the regions of groundwater extraction (>15 mgNO_3/l). Under natural conditions (where the water extraction is not performed) this contamination is not yet observed in deep part of the flow system and the concentration of nitrate is low. In this condition in deep part of the aquifer typical stagnation zone exists (as defined by Toth, 1963), what is manifested by completely different groundwater chemistry than in shallow part of the aquifer. The presented research is a great example how chemical data can support investigation of groundwater flow conditions and formulation of the conceptual model of groundwater circulation.
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Behaviors of nitrate in unsaturated zone in groundwater recharge area in Kumamoto, southern Japan

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KEY WORDS soil water, nitrate, isotope ratios, fertilization, denitrification

ABSTRACT
Nitrogen loads thought agricultural activities can trigger groundwater nitrate contaminations. Once it loaded at the surface, nitrogen compounds may change its form in soils due to biogeochemical reactions prior to reach to aquifer. However, nitrate behaviors with the time scale of its transportation, from the surface, though unsaturated zone, to aquifer systems, is poorly known. To clarify the behaviors of nitrogen together with its transportation time scale, oxygen-hydrogen isotope ratios of water and nitrogen-oxygen isotope ratios of nitrate of the soil water from the farmlands with different fertilization logs were analyzed. We collected four soil cores (~ 20 m) in farmlands in Kumamoto, southern Japan, where is the major nitrogen source region for groundwater contamination in this area. The cores S1 and S2 were collected from farmlands applied both slurry and chemical fertilizers, whereas, cores C1 and C2 were from those applied chemical fertilizers. All soil samples were sectioned into 10 cm intervals, kept on evacuated condition in the field, and in the laboratory soil water were extracted for chemical and isotope analysis. The results of numerical model using oxygen-hydrogen isotope ratios of water suggested that downward velocities of soil water are in a range of 1-2 m/yr for all cores and travel times from the surface down to the aquifer systems are estimated between 10-30 years depend on core sites. The nitrate concentrations were high at the 0-10 m in the range between ca. 100-200 mg/L for all cores, suggesting high contamination potential source. Furthermore, nitrogen and oxygen isotopic results indicated that occurrence of denitrification were not important, except in the surface layers of the core S1 and S2, which samples showed significant isotopic fractionations (up to 37‰ in nitrogen isotope ratio). More importantly, data comparison of vertical profile between oxygen isotope ratios and nitrate concentrations provided an interpretation that downward transportation velocities of nitrate should be faster than that of soil water. These findings can supply key aspect in groundwater management and preservation as a basic information. In the presentation, we will present detailed discussions regarding the behaviors of the nitrate in unsaturated zone.

Code of abstract: T4.2.34
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.2. Monitoring of groundwater quality and contamination

Geochemistry and Evolution of the Water-rock Systems, using Trace and Rare Earth Elements in Upper Awum Catchment, Lower Niger River Basin. North-Central Nigeria

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KEY WORDS: Rare Earth geochemistry, REEs distributions, Ce-Eu-Pr anomalies, Awum-river catchment and Water-rock interactions.

ABSTRACT
The distributions of trace and rare-earth elements (REEs) in surface, and ground natural were evaluated to examine the rare earth geochemistry and major processes of water-rock interactions. Nine (9) Surface and nineteen (19) deep well water samples were analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Awum river catchment is part of lower Niger River Basins. In the study, the results showed that the REEs patterns in surface water reflected the source rock patterns with high rare earth elements (HREE). The chondrite normalized patterns of REEs showed enrichment of LREEs over HREEs with positive Ce/La ratio. The positive Ce/La ratio is a reflection of groundwater derived from carbonate sediments. The REEs concentrations in the study area were found to be of geogenic origins and the distributions were not influenced by anthropogenic sources. Three (3) clusters were identified, which reflects geogenic (Si, Rb, Ba), REEs (Ce, La, Ge, Sm, and so on) and Transition elements (Pb, Cr, Co, Zn, etc). Negative Ce, Positive Pr and Eu anomlies were observed, the negative Ce anomaly connotes reducing oxic condition as a result of preferential uptake of Ce by organic compounds and Fe-Mn oxides.

Code of abstract: T4.3.1
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Chasing the tracer - combining conventional salt tracer testing with direct push electrical conductivity profiling for enhanced aquifer characterization

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KEY WORDS Tracer testing, direct push profiling, aquifer characterization

ABSTRACT
Reliable parametrization is a prerequisite for reliable simulation of flow and transport processes within the saturated zone. This is especially important for aquifer systems that are strongly affected by the dynamics of groundwater-surface water interaction. Tracer testing is a well-established and commonly applied technique for the hydraulic characterization of the subsurface. However, this technique is seldom used under dynamic conditions as a prior knowledge about the hydraulic regime is needed to determine the layout of the tracer test field. A typical example representing these dynamic conditions can be found at the highly permeable gravelly and sandy deposits of the Tagliamento River, Italy. Investigations were performed near the city of San Daniele del Friuli to characterize hydraulic properties of the channel-adjacent deposits. Only very limited information was available on groundwater gradient and flow-field prior to well installations and stream gauge level changes can be observed within short time periods. For enhanced subsurface characterization, conventional salt tracer testing was combined with Direct Push electrical conductivity logging. Therefore, a salt tracer was injected in a two inch direct push-installed well. After tracer injection, direct push high resolution vertical electrical conductivity profiling was performed in concentric hemicycles around the injection well to identify the main direction of tracer propagation, tracer velocity, and tracer plume geometry. Based on the results, positions of monitoring wells were rapidly adapted. Results show that the combined use of conventional salt tracer testing with Direct Push electrical conductivity logging is an efficient strategy for the characterization of highly permeable sedimentary deposits with groundwater velocities of several meters per hour.

Code of abstract: T4.3.2
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Comparison of Characterization Methods Used to Develop Conceptual Models for Discrete Fracture Networks

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KEY WORDS fractured rock, characterization, pulse interference tests, tracer experiments, hydraulic tests

ABSTRACT
The development of conceptual models for solute migration in discrete fracture networks is often based on a combination of core logs, borehole or hydro-geophysics, and single-well hydraulic tests conducted using discrete zones. We typically assume that inter-well hydraulic tests and inter-well tracer experiments will provide a between estimate of potential transport pathways. As the costs of inter-well tests are high, these tests are less likely to be applied at a typical contaminated site. In the present study, a detailed comparison between single-well and inter-well methods is conducted by developing conceptual models from three separate data sets, the first based on core logs, geology and single-well hydraulic tests, the second based on inter-well pulse interference tests, and the third based on a series of tracer experiments. The study was conducted in an array of five 96-mm wells, 28-32 m in depth and arranged in a five-star pattern, 10 m on a side. The wells penetrate the contact between a Cambrian-aged limestone, and underlying Precambrian gneiss. The core was logged for potentially open fractures using a ranking system, and 87 contiguous hydraulic tests were conducted using a 0.85-m packer spacing. A total of 57 pulse interference tests were conducted using two wells as injection points, and 11 tracer experiments were conducted using either sample collection or in-situ detection via a submersible fluorometer. The results showed very dissimilar conceptual models between each data set, with the model based on the single-well testing significantly over-predicting the number and connection of potential solute transport pathways. The results of the pulse interference tests also over predict the transport pathways, but to a lesser degree. Notably, even though the tracer experiments are likely to provide the most robust estimates of the transport pathways, these are subverted by the use of induced and not natural hydraulic gradients.

Code of abstract: T4.3.3
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Monitoring groundwater-surface water interactions through radon tracer and microbial diversity around ground water heat pump system

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KEY WORDS - Groundwater-surface water interactions, Radon, Microbial diversity, Ground water heat pump system, Mixing ratio

ABSTRACT

This study aims at investigating interaction characteristics between groundwater and surface water under river stage fluctuations in Yangsu-ri, Korea where groundwater has been used as renewable energy sources for space heating and cooling. A multi-disciplinary approach, combining hydrogeochemical parameters, radon isotope analysis, and the interpretation of microbial diversity data, was performed for 13 water samples including one surface water from May, 2014 to Apr., 2016. Groundwater level and river stage fluctuations had been also observed. The radon tracer proved the usefulness in delineating flow patterns and quantifying the mixing process between two water bodies, which have contrasting values. The spatial distribution of groundwater radon concentrations was changed in accordance with the river flow direction, representing the strong influence of river water on groundwater. The calculated mixing ratio showed that groundwater was actively mixed with the infiltrated surface water during periods of dam discharge events or heavy rainfall. The average value of surface water ratio is much higher (37.1 percent) in the study site than that in general site, suggesting that river flow would have a considerable temperature impact on the operation of GWHP. The pyrosequencing data showed that each water sample has its own distinct bacterial community composition, dominated by Actinobacteria, which was related with river stage fluctuations. The Unifrac UPGMA cluster analysis was in good agreement with that revealed by radon concentration, indicating that data was also affected by the combined effect of the mixing processes and groundwater pumping. Our results suggest that here new multi-tracer approach is efficient to interpreting the groundwater-surface water interactions considering GWHP operations.

Code of abstract: T4.3.4
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Relationship between the isotopic characteristics of local precipitation and groundwater

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KEY WORDS stable oxygen isotope, tritium, precipitation, infiltration, shallow groundwater

ABSTRACT
The infiltration rate of local precipitation into the subsurface aquifers changes seasonally, generating a difference between the weighted mean of stable isotopic composition of the local precipitation and the infiltrated water. Usually the infiltrated water is isotopically lighter, because the rate of infiltration of the isotopically heavier summer precipitation is lower than that of the winter precipitation.
We have compared these two types of waters in different parts of Hungary to see whether this difference depends on the topography or not. We have used $\delta^{18}O$ mean values of precipitation of the years 2013-2014 (Czuppon et al., 2015), except two stations on the Great Hungarian Plain, where we used data of longer periods. The $\delta^{18}O$ measurements on the shallowest groundwaters were carried out during the latest 27 years. Selections of modern infiltrations were based on tritium activity and hydrogeological information.
On the Great Hungarian Plain the $\delta^{18}O$ values of both the multi-annual mean of precipitation and the groundwater are rather homogeneous, and there is no big difference between the precipitation and the infiltrated water, the latter one is usually more negative by few tenth of per mill. While in the hilly Transdanubia (Western Hungary) this relation is not so straightforward. There are significant differences between the $\delta^{18}O_{prepitation}$ values of the different sites in spite of the small difference in their altitude (elevation above sea level). While the differences between the $\delta^{18}O_{groundwater}$ values of the different sites are smaller than in the case of precipitation, yet significant. In one case the $\delta^{18}O_{groundwater} > \delta^{18}O_{prepitation}$, which is exceptional. The explanation for this virtual phenomenon is probably the fact that groundwater represents decades of years, while precipitation data represents only two years, and extreme events (years) may shift the measured $\delta^{18}O$ significantly from the multi-annual average.
The research was financially supported by National Research, Development and Innovation Office (project NKFIH, OTKA 101664; PD 121387and SNN118205). György Czuppon also thanks for the support of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

Code of abstract: T4.3.5
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Geochemical methods for characterisation of organic material and groundwater in upland peat swamps

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KEY WORDS - swamp, dissolved organic matter fluorescence, stable water isotopes, pore water, carbon and nitrogen isotopes

ABSTRACT

Upland peat swamps are developed in valleys that overlie Triassic Sandstone in the Sydney Basin (Australia) with endemic flora and fauna species that are dependent on saturated and moist conditions. These upland swamps, typically located between 600 to 1200 m above sea level, are protected and listed as threatened ecological communities under Australian and State government regulations. However, many of those swamps have been degraded by stormwater runoff from urban areas, erosion, fires and the effects of underground mining (Robarts et al., 2013; Fryirs, 2016).

This research was undertaken to understand what geochemical methods can assist in characterising the swamps by looking at the intact swamps and the swamps which have been impacted by human activity. This was achieved by collecting geology information, sediment, peat, roots and leaves samples and groundwater, surface water and pore water samples over two monitoring events in winter and later spring. These samples were collected by augering holes to refusal up to 2m depth and groundwater samples from existing shallow (in peat) and deep piezometers (in sandstone). The samples were analysed for the following: $\delta^{18}O$ and $\delta^{2}H$ stable water isotopes, swamp pore water stable isotopes, fluorescence of dissolved organic matter, $\delta^{13}C$ and $\delta^{15}N$ stable isotopes of swamp organic matter and major ion chemistry on surface and groundwater. In addition, the moisture content and organic matter content (loss on ignition) was measured on all sediment and peat samples.

The study found at all swamp sample sites (n = 9), peat was underlain by fine sand occasionally clayey, overlying partially weathered sandstone at the base of the swamp. Groundwater and pore water stable isotope analysis confirmed that both pore water from peat and underlying sediment, surface water and groundwater plot close to the meteoric water line. Surface water samples were found to be distinctly different from pore water from shallow peat and sand. All pore water samples showed a strong evaporation trend. $\delta^{18}O$ and $\delta^{2}H$ stable isotopes identified the water origin, while carbon and nitrogen isotope results showed that these can be useful indicators of the swamp source of material. The results indicate the depletion of $\delta^{15}N$ in surficial matter compared to samples at depth and enrichment in one of the swamps.

Code of abstract: T4.3.6
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

CO_2-infused groundwater and gas tracers leakage test using shallow-depth groundwater and gas monitoring network

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KEY WORDS - CO_2 leakage, CO_2-infused groundwater, inert gas tracers, groundwater and gas monitoring network

ABSTRACT
The effectiveness of CO_2 leakage characterization is highly dependent of reasonable monitoring network designs for detecting the CO_2 leakage under various hydrogeological conditions. Also, the migration of CO_2 through heterogeneous subsurface is not easy to predict because small differences in material properties may result in vastly different migration patterns. The groundwater and gas monitoring networks considering hydrogeological characteristics were constructed to perform an artificial CO_2 leakage test into a shallow aquifer at EIT site, Eunseong, Korea. The main purpose of CO_2 release test is to understand the behavior of CO_2 plume and inert gas tracers (Kr, Ar, He, and SF_6) in a shallow aquifer system. About 5,000 L of CO_2-infused groundwater were injected into a shallow aquifer. For the CO_2-infused water injection, pre-pumped groundwater was mixed with CO_2 gas (through the gas dissolver) as well as multi-gas tracers (Kr, He, and SF_6 using gas aeration method). After injection period, about 2,500 L of chaser fluid, Ar-infused water, was injected to push the CO_2 plume out of the injection well into the aquifer. The real-time monitoring for injection test had been performed during about 4 months. Spatial and temporal trends of measured values for soil gas CO_2 and SF_6 at unsaturated zone, hydraulic parameters (pH and EC), and dissolved CO_2 and gas tracers at saturated zone were analyzed. Based on a time-concentration data of gas tracers obtained from preliminary inter-well tracer test, gas solubility was determined as a major factor governing the phase partitioning of tracers. Among partitioning tracers, Kr was firstly reached at around monitoring wells and maintained a detectable concentration which was longer detection time than other gas tracers. In the main test, the effect of injection was faintly represented on tracer concentration, water-level, temperature, EC, and TIC data obtained from monitoring wells adjacent to injection well due to a small amount of injection. The radius of influence by injection test was estimated as about 3 m. It was supposed that injected CO_2 plume did not migrate far away from injection well. Results from monitoring data can be utilized for site assessment and operation of monitoring network at EIT site for next long-term CO_2 injection experiment with increased injection volume.

Code of abstract: T4.3.7
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Comparative study of regional distributions of stable isotopic ratios of hydrogen and triple oxygens in spring water and irrigation-pond water across Japan

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KEY WORDS spring water, irrigation-pond water, stable isotopes of hydrogen and triple oxygens, regionality

ABSTRACT
This study demonstrates the use of stable isotope ratios of hydrogen and oxygen as a tracer to provide a basis for understanding the relation between irrigation water and groundwater in hydrologic cycles across Japan. Stable isotope ratios of hydrogen and triple oxygen were surveyed at 60 spring water sites and 57 irrigation pond sites, which are important water sources for paddy rice fields, in 31 prefectures during irrigation periods in 2015 and 2016.
The deuterium excess (d-excess) values of spring waters on the different ocean sides of the archipelago could be clearly distinguished. The regionality of d-excess distribution appears in irrigation-pond water. This different spatial distribution can be explained by the different proportion of summer and winter season rainfalls with different d-excess values. Stable isotopic ratio of $^{18}O/^{16}O$ and ^{17}O-excess, which assesses anomaly from an expected relationship between ^{17}O and ^{18}O, of spring water and irrigation-pond water are negatively correlated as shown in other published research. The spatial distribution of ^{17}O-excess provides the first view of ^{17}O-excess values of meteoric water in Japan, and could be supplementarily used for an estimate of groundwater origin in a hydrological cycle.
The stable isotopes of irrigation-pond water were enriched as a result of evaporation and plot below the Local Meteoric Water Line of Japan. Therefore, the d-excess of irrigation-pond water tends to be lower than d-excess of spring water at the same latitude. The mean residence time of irrigation-pond water is estimated at about 110 days, which is shorter in comparison with standard lakes in Japan. It is thus deduced that irrigation-pond water collected during an irrigation period (from May to September) is mainly composed of summer rainfall and is affected by evaporative enrichment of stable isotopes.
These results thus indicate that there is the regional difference in the stable isotopic ratios of spring water and irrigation-pond water, and the difference is considered to arise from the different proportion of summer and winter season rainfalls to annual precipitation. In addition, a heavy isotope enrichment of irrigation-pond water is strong evidence that the irrigation ponds in Japan are affected by evaporation from open water surface.

Code of abstract: T4.3.8
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Fluorescent Dye Tracing in Thermally Enhanced Bioremediation: Laboratory Experiments on Biodegradation and Solute Transport of Eosin Y

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KEY WORDS: Fluorescent dye tracing, Eosin Y, Enhanced bioremediation, Batch and column experiments

ABSTRACT

Fluorescent dyes find widespread application in answering hydrogeological questions: from revealing hydraulic connections between catchments and springs, over identifying preferential groundwater flow paths, to tracing dissolved contaminants and particle transport, and more.

In a pilot project in Chiba, Japan, the applicability of fluorescent dyes as a tracing and monitoring tool for the organic substrate solution in thermally enhanced bioremediation of volatile organic compounds was tested. The groundwater temperature in the 20x13x10 m^3 test site was raised from 15-17°C to 25-35°C by warm water injection. The fluorescent dye was injected in intervals together with a bio-stimulating organic substrate solution. The fluorescent dye selected in this works was Eosin Y (Acid red 87) for its low pH dependency until a pH-value of 4, low to moderate sorptivity, and low detection limit compared to other fluorescent dyes available. This study presents the results from batch and column experiments conducted in order to determine the effects of an increased temperature and the presence of a bio-stimulant on the solute transport and microbial degradation of Eosin. In batch experiments, solutions of Eosin and bio-stimulant in groundwater were stored under anaerobic conditions at 17°C and 30°C for up to eight weeks. Degradation rates were obtained from total organic carbon (TOC) and fluorescence intensity (FI) measurements after 0, 1, 2, 4 and 8 weeks. In column experiments at 20°C and 30°C, solutions of Eosin and/or bio-stimulant were pumped at a constant rate through packed soil, sampled silty fine sand from the test site in Chiba, Japan. The collected samples were analyzed for TOC and FI. Diffusion coefficients and retardation factors of Eosin were derived from the obtained breakthrough curves.

The parameter determined in this study's laboratory scale experiments serve as starting points for the parameterisation of the bio-stimulant injection control system's underlying groundwater flow model. Further, the findings of this research provide reference values for a plausibility check of data recorded during the field application of Eosin Y in thermally enhanced bioremediation.

Code of abstract: T4.3.9
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Fluorescent Dye Tracing in Thermally Enhanced Bioremediation: Monitoring of spatio temporal organic substrate distribution using Eosin Y – a case study

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KEY WORDS: Fluorescent dye tracing, Eosin Y, Organic substrate, Thermally Enhanced Bioremediation, In situ testing

ABSTRACT

BACKGROUND
An effective thermally enhanced bioremediation system coupled with aeration of the circulating groundwater was developed in order to speed up the remediation process of soil contaminated with volatile organic compounds (VOC). This system is designed to stimulate anaerobic degradation of VOC by raising the groundwater temperature close to 30°C in addition to periodic injections of organic substrate. The injection intervals were controlled by a monitoring and feedback system observing the heat and substrate distribution in the aquifer.
It is well known that measuring the concentration of the substrate solution by total organic carbon (TOC) at the site is difficult. In order to control the heat and substrate distribution, we applied a fluorescent dye as a tracer of the organic substrate solution for real time monitoring.

METHODOLOGY
The purpose of this study was to maintain a uniform temperature and organic substrate distribution in the test site within ±10% of the targeted values, and to evaluate the fluorescence dye tracer Eosin Y as a viable tool for monitoring the temporal and spatial substrate distribution in thermally enhanced bioremediation.
The field experiment was carried out in uncontaminated silty fine sand in Chiba, Japan. The aquifer at the test site extended from 6m below ground level and was surrounded by sheet piling to a length of 20m, a width of 13m, and a depth of 19m. The water circulation was controlled by two injection wells and two pumping wells. Over a period of 7 months, TOC and fluorescence intensity were measured from samples, whereas temperature was recorded continuously. In addition, an automatic fluorescence detection system for a remote controlled continuous measurement of Eosin was tested.

RESULT
This study presents the schematic design of the thermally enhanced bioremediation system and the findings after 7 months of continuous operation. The temperature was successfully controlled within the target range of 30±3 °C.
The organic substrate was over 100mg/L, the target value. There was a divergence of arrival times between the substrate and Eosin. We estimated that the divergence was caused by differences in dispersion and degradation properties, and preferential flow paths.
In addition, we found heterogeneities in hydraulic conductivity between observation wells by measuring the temperature distribution.

Code of abstract: T4.3.10
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.3. Tracer experiments and application of natural isotopes in groundwater studies

Isotopic composition of currently infiltrating water in Roztocze (SE Poland)

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KEYWORDS - water isotopes, precipitation, springs, aquifers

ABSTRACT

In the years 2014-2015, analyses were carried out to determine the isotopic composition of atmospheric precipitation water and groundwater from the zone of active exchange in the Sanna River catchment in Roztocze (SE Poland). The study area is characterised by a low density of the river system, favourable conditions for water infiltration, complex geological structure, deep levels of groundwater table, and local occurrence of suspended horizons. For the analysis of the isotopic composition, water samples were collected at week intervals from a spring draining porous Quaternary rocks and solid rocks of the Late Cretaceous opoka-type; precipitation water was sampled as well. Measurements of spring discharge and the ground water levels were performed in dug wells with installed automated water level recorders. The ratios of natural isotopes δH/D and δ12C/13C were measured with a Picarro L2130 laser spectrometer. During the analysis, the device was calibrated using solutions with known isotopic ratios in VSMOW: OH-13, OH-14, OH-15, OH-16, GISP. The precipitation waters exhibited values of δ18O -62.4 ‰, δD -8.5 ‰. The groundwater outflowing from porous formations had values of δ18O -68.5 ‰, δD -9.8 ‰, and waters of the spring draining solid Late Cretaceous rocks - δ18O -72.1 ‰ , δD -10.2‰. The investigation results indicate that the isotopic composition of the waters was similar to the world precipitation line. Changes in the isotope ratios of precipitation waters were related to seasonal changes in air temperature, and those in the groundwater - to spring discharge. Isotopic ratios and data concerning changes in the discharge and location of the water table in wells indicate relatively rapid circulation of water and the importance of the Quaternary horizon, which extends its circulation time. It is a suspended horizon present locally at 30-40 m over the main Cretaceous aquifer, which has a significant impact on the chemism of underground waters and evapotranspiration. The isotope ratios of the analysed waters (H/D, 16O/18O) suggest their modern origin; the noted differences were associated mainly with meteorological conditions and the thickness of the vadose zone, which ranges from a few to several dozen meters in the area of the “suspended horizon”.

Code of abstract: T4.4.1
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

"MétéEau des nappes": a decision making tool to characterize in almost real-time groundwater quantitative state.

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KEY WORDS - groundwater level forecasting, almost real-time data flows, interoperability, OGC, SensorWeb

ABSTRACT

In a climate change context, the availability of real time and forecast piezometric data is essential information for decision makers. Indeed, associated with threshold values (groundwater levels corresponding to different alert discharges values) those data can indicate if a crisis situation is expected, either drought or flooding episodes.

To meet societal expectations, BRGM (French geological survey) currently works on improving its national piezometric data network. Raw data from sensors are exposed in interoperable formats and services in accordance with international open standards for sensorWeb interoperability and European rules (INSPIRE directive guidance on the use of Observations & Measurements and OGC SWE - Sensor Web Enablement Framework).

The objective of the "MétéEau des Nappes" project is to deploy an interoperable communication tool unable to cross data from different networks (meteorology, river flow, piezometric) in order to characterize in almost real-time groundwater quantitative state. A prototype of this tool was deployed on a few selected French regions with different hydrogeological characteristics and various issues (drought or flooding).

Preliminary steps were to define case studies (watersheds) to select the representative piezometers and the corresponding measured stations and, eventually to calibrate models that provide piezometric level forecasts. At the present stage, the tool shows maps giving the location of measured stations and charts drawing the real time evolution of data compared to thresholds and model predictions. It also provides the model predictions as a Sensor Observation Service in addition to the raw data flows.

BRGM also contributes to the achievement of the national hydrological situation report (monthly evolution of water resource) on behalf of the French ministry of Environment. Then the final step of the project is to integrate into the tool a map showing specified indicators of the groundwater state and trends.

Perspectives of the project are the implementation of data assimilation and automatic forecasting processes into the models.

Among the French stakeholders interested in the tool, we can indicate: Water agencies, decentralized services of ministries, Regions and Departments, Association of Municipalities, Industrial water producers…

Code of abstract: T4.4.2
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Characterizing groundwater heads with online interactive time series analyses

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KEY WORDS monitoring, head, automatic, interactive, characterization

ABSTRACT
The Geological Survey of the Netherlands (GSN) provides data about the subsurface through the website http://www.dinoloket.nl. Among these data are over 35,000 measured groundwater heads. The head time series implicitly contain a lot of information about the groundwater system, such as the response of the groundwater head to precipitation and evaporation. GSN wants to make more of this information available so that the authorities responsible for the groundwater management can carry out their task more efficiently.

Time series models offer the opportunity to generate such information. Therefore, time series models have been generated automatically for piezometers throughout the Netherlands. The time series models are transfer-noise models. The quality of these models is checked using a variety of criteria. In order to quantify these criteria 388 groundwater head time series have been selected: (a) within the province of Utrecht (a region with distinctly different groundwater systems), (b) length of at least 20 years (in order to have enough data for statistical analysis), (c) last measurement after 2011 (to be able to describe the current hydrological situation).
Using the criteria resulting from these analyses, a framework has been setup to present the information from the time series analysis online using an interactive web service. On this web service graphics characterize the current groundwater situation daily, which is independent of the measurement frequency (which often is 2-weekly). The characteristics can be determined for different periods to estimate structural variations in time. The Time Series Analysis Tool can be used together with a Spatial Interpolation Tool to automatically get spatially distributed information about the groundwater system contained in piezometer data.

Code of abstract: T4.4.3
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Combining different techniques to monitor seawater intrusion integrating different observation scales.

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KEY WORDS: Cross-hole electrical resistivity tomography, fiber optics, downhole logging, saline intrusion, alluvial aquifer.

ABSTRACT
The characterization of saline water interface and understanding its hydrodynamics is a key issue to manage groundwater resources in coastal environments. In order to test and combine different monitoring techniques, a new experimental site has been constructed north of Barcelona city (Spain) in the lowest part of an alluvial aquifer. The objective is to improve the understanding of the dynamics of the seawater interface at different scales. The site, between 30 and 90 m from the seashore comprises 16 shallow piezometers with depths ranging between 15 and 25 m.

All piezometers are equipped with Fiber Optic (FO) cable to perform distributed temperature measurements. Two fibre optic cable lines of around 600m length each were installed around all boreholes. FO allows to measure temperature at 25 cm resolution along the installed line were the thermal effect of the different boundary conditions may be identified. Deepest piezometers are also equipped with electrodes every 75 cm in order to perform cross-hole electrical resistivity tomography (CHERT). This technique allows to represent a vertical cross section perpendicular to the sea where the fresh-salt water interphase can be inferred due to the resistivity contrast between the saline and fresh water. This two methods are complemented with downhole electrical conductivity logging in some specific boreholes allowing to measure pore fluid conductivity changes at high temporal resolution (every 10 min).

In this presentation we show two snapshots of the data obtained with these techniques for June and September 2015. These techniques give us information at different spatial and temporal resolution. However, its combination helps to understand better the hydrodynamics of the seawater interface, which may have relevant implications to understand biogeochemical cycles in the interface and for groundwater resources management.

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Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
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Measuring changes in groundwater flow using fibre optic active distributed temperature sensing in bedrock boreholes

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KEY WORDS – DTS, Bedrock Aquifer, Groundwater Flow, Thermal, Distributed Fibre Optic Sensing.

ABSTRACT

Identifying specific intervals of natural groundwater flow in bedrock aquifers is inherently challenging due to the discrete nature of the flow paths and need to restore natural gradient conditions. Active distributed temperature sensing (A-DTS) in temporarily sealed coreholes has been shown in recent years to be a powerful tool for identifying such features. We present the results of several field experiments where A-DTS tests were collected under different gradient conditions to assess the sensitivity of the approach to changes in groundwater flow. The experiments were conducted at the Bedrock Aquifer Research Station on the University of Guelph campus, which consists of a cluster of nine coreholes (6 vertical and 3 inclined) closely spaced from 7.5 m to 70 m apart, in a 75 x 75 m area. A composite fibre optic cable was installed in eight of the coreholes and spliced together at the surface to form a continuous loop of approximately 1750 m. This allowed A-DTS tests to be carried out along multiple coreholes simultaneously. The A-DTS tests were conducted under natural gradient conditions where all coreholes were temporarily sealed with flexible liners, as well as under modified gradient conditions where hydraulic cross-connection or pumping was occurring. Results demonstrate clear thermal responses at discrete fractures and solution channels where groundwater flow varies proportionally to changes in gradients. The results provide insight as to what fractures or solution channels are interconnected and hydraulically active and allow assessment of the sensitivity of the A-DTS in bedrock aquifers.

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Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Monitoring and Mapping Groundwater Flooding In Ireland.

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KEY WORDS - Groundwater Flooding, Karst, Turloughs, Ireland

ABSTRACT
The phenomenon of groundwater flooding represents a significant flood hazard for many rural communities in Ireland. Groundwater flooding is primarily associated with lowland karstified limestone areas prevalent in the west of the country. These areas are susceptible to groundwater flooding due to the combination of low soil and aquifer storage, high diffusivity and limited surface drainage characteristic of the region. Unprecedented flood events in recent years have reinforced the need for a greater understanding of groundwater flooding as a geohazard, and improve our ability to quantify the location and likelihood of flood occurrence. In response, Geological Survey Ireland has established a new collaborative groundwater flood programme (GWFlood) with University of Dublin Trinity College.

Key objectives of the GWFlood project are to monitor and map groundwater flooding in Ireland to an unprecedented extent. A monitoring network of over 60 sites has been established over the winter of 2016/2017 to improve our understanding of the hydrodynamics and flooding potential of Irish karst systems. Remote sensing data from Landsat (NASA/USGS) and Sentinel (ESA) satellite programmes have been used to generate high-resolution flood extent maps on a catchment-scale. Time series of Synthetic Aperture Radar (SAR) images have also been combined with high resolution topography maps to construct hydrographs for previously unmonitored sites affected by groundwater flooding.

This new programme will provide the fundamental hydrological data to enable key stakeholders to develop appropriate flood mitigation measures and allow for informed flood assessments to be made in future.

Code of abstract: T4.4.6
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Recent changes in terrestrial water storage in the Upper Nile Basin: an evaluation of commonly used gridded GRACE products

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KEYWORDS: GRACE satellite products; terrestrial water storage; groundwater; hard-rock aquifers; Sub-Saharan Africa

ABSTRACT

GRACE (Gravity Recovery and Climate Experiment) satellite data monitor large-scale changes in total terrestrial water storage (ΔTWS) providing an invaluable tool where in situ observations are limited. Substantial uncertainty remains, however, in the amplitude of GRACE gravity signals and the disaggregation of ΔTWS into individual terrestrial water stores (e.g. groundwater storage). Here, we test the phase and amplitude of GRACE ΔTWS signals from 5 commonlyused gridded products (i.e., NASA's GRCTellus: CSR, JPL GFZ, GRGS; JPL-Mascons; GRGS GRACE) using in situ data and modelled soil-moisture from the Global Land Data Acquisition System (GLDAS). The focus of this analysis is a large and accurately observed reduction in ΔTWS of 75 km^3 from 2004 to 2006 in Lake Victoria in the Upper Nile Basin. We reveal substantial variability in current GRACE products to quantify the reduction of ΔTWS in Lake Victoria that ranges from 68 km^3 (GRGS) to 50 km^3 and 26 km^3 for JPL-Mascons and GRCTellus, respectively. Representation of the phase in ΔTWS in the Upper Nile Basin by GRACE products varies but is generally robust with GRGS, JPL-Mascons and GRCTellus (ensemble mean of CSR, JPL and GFZ time-series data) explaining 91%, 85%, and 77% of the variance, respectively, in in-situ ΔTWS. Resolution of changes in groundwater storage (ΔGWS) from GRACE ΔTWS is greatly constrained by both uncertainty in modelled changes in soil-moisture storage (ΔSMS) and the low annual amplitudes in ΔGWS (e.g., 3.5 to 4.4 cm) observed in deeply weathered crystalline rocks underlying the Upper Nile Basin. Our study highlights the substantial uncertainty in the amplitude of ΔTWS that can result from different data-processing strategies in commonly used, gridded GRACE products.

Code of abstract: T4.4.7
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Implementing of geophysical methods to monitor seawater intrusion in multi-layered coastal aquifer

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KEYWORDS: saltwater intrusion, coastal aquifer, geophysical observatories, pumping effect

ABSTRACT

Geophysical methods were applied to study the hydrological relations between a multi-layered coastal aquifer and the sea in the coastal aquifer of Israel. The Quaternary aquifer in the studied site is in a thickness of 40 m and is sub-divided into three units – a sandy, phreatic unit (A) and two confined sandstones units (B and C). The sandstone units are extensively exploited by pumping's well located 150 – 600 m from coastline. TDEM survey show seawater intrusion in unit B while fresh water in unit A and C.
Subsurface Monitoring Devise (SMD) was installed in a 2" monitoring well to unit B, located 70 m from coastline. The SMD includes series of electrodes that inserted to the well and take measurements of the resistivity of the rock formation around the borehole (sediment and fluid) every meter and every hour, which is translated after calibration to electric conductivity values of the water. The data is transferred by telecommunication and may be visible "on line" in the computer office. Since the SMD measured the resistivity mostly outside the well (at diameter of ~0.5m), it is important to note that the salinity change occurs in the aquifer and not "well interference" phenomena.
During the year 2016, the SMD show clear evidence for increase in salinity and hence for seawater intrusion, indicating that significant reduction of the pumping rate is necessary for preventing wells salinization. We also found that the EC profile in the monitoring well is effected by pumping regime in a specific well, whereby when pumping was stopped, the EC is increased in the lower 3 m. This finding implies that the interpretation of EC profile for estimating the interface movement should be done carefully since it may change temporary. Moreover, the increase in salinity while pumping is stopped was surprising since pumping is usually considered the main factor for seawater intrusion. The high frequency of measurements and the telecommunication make the SMD tool very powerful for monitoring seawater intrusion.

Code of abstract: T4.4.8
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Evaluating Groundwater Level Change in Yangsan Fault Zone due to small-scale earthquakes, South Korea

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KEY WORDS - groundwater change, change factor, earthquake, groundwater monitoring, time-series data

ABSTRACT
This study was carried out to evaluate the influence of earthquake using groundwater level data in Yangsan fault zone in South Korea. It was challenging to evaluate irregular, variable changes of the groundwater levels. In general, many factors affecting groundwater level are such as groundwater recharge due to precipitation, capture of air, evapotranspiration, etc. as well as earthquake. It is difficult to separate groundwater level change due to earthquake from other factors. In this study, we revealed the characteristics of groundwater level change influenced by groundwater recharge and earthquake.
For this study, we measured groundwater level every minute and transformed the raw data to change rate per minute in order to extract level change by the earthquakes. Groundwater level responded to the earthquakes of magnitude (M) 4.0 or more with a maximum 0.04 m of groundwater level change. To analyze the influence of precipitation, we compared rainfall amounts with groundwater level at similar times. For instance, despite 119.0 mm of the rainfall amount on 17 September, 2016, groundwater level fluctuation did not change. However, Gyeongju earthquakes of magnitude (M) 5.1 and 5.8 occurred on 12 September, 2016, produced a rapid decline of 0.04 m and 0.03 m, respectively. Therefore, it can be concluded that the shock wave generated by the earthquake changed normal groundwater level fluctuation.
By the earthquakes between M 4.0 and 5.0, oscillation pattern of the groundwater level change was observed. By contrast, the earthquake of M 5.0 or more triggered a sharp change of the groundwater level. In the future, it will be necessary to analyze the groundwater level patterns through various time series approaches with filtering techniques, following to measure groundwater level by using more sensitive instrument at a shorter time interval.

Code of abstract: T4.4.9
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.4. Application of remote sensing and geophysics techniques in groundwater monitoring

Hydrogeophysical investigation of the fresh water-salt water distribution above a salt dome

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KEY WORDS -Airborne Electromagnetics, Direct Push, Hydrogeophysics

ABSTRACT
Extensive hydrogeological exploration programs have been used for mapping and monitoring the fresh water-salt water interface above a salt dome in Germany. For this purpose an airborne electromagnetic survey (AEM) utilizing the SkyTEM system and a Direct-Push electrical conductivity profiling combined with Cone-Penetration tests were applied.
The case study is used to demonstrate how knowledge from wells, boreholes and chemical analyses can be extended using combined hydrogeophysical surveys in order to improve hydrogeological and geological interpretations.

The interpolated airborne electromagnetic 1D inversion results were analyzed and the general hydrogeological system and large-scale geological structures in the investigated area were identified. Direct-Push technologies were used for verification of the AEM results and to precisely delineate the local underground heterogeneity. The interpretation of hydrogeophysical data using additional hydrological and geological information led to the identification of distinctive areas of mineralized groundwater and transition zones between fresh and salt waters.
In this context combined hydrogeophysical applications can be used to reveal comprehensive information to the fresh water-salt water distribution over the whole study area. Furthermore they are a powerful tool to support monitoring networks, geological mapping and groundwater models.

Code of abstract: T4.5.1
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.5. Groundwater resources evaluation and management under arid conditions

^{81}Kr Dating of ancient ^{14}C-depleted water: an example from the Nubian Sandstone Aquifer of the Negev Desert (Israel)

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KEY WORDS Dating, Krypton isotopes, Radiocarbon, Nubian Sandstone Aquifer

ABSTRACT

The deep Nubian Sandstone Aquifer under the Sinai Peninsula (Egypt) and Negev Desert (Israel) contains large amounts (>2×10^{11} m^3) of fresh-to-brackish water with negligible modern recharge. Hydraulic-head gradients suggest groundwater flow from the main recharge zone in southern Sinai toward the natural eastern outlets near the Dead Sea and The Gulf of Aqaba. Groundwater in this aquifer was previously dated using the common ^{14}C ($t_{1/2}$=5,730 years) dating method; contradicting the aquifer's clear hydraulic gradients toward the outlets, relatively homogeneous apparent ages of 20,000–35,000 years were estimated throughout most of the basin, ostensibly suggesting a single-massive recharge event which filled the aquifer during the late Pleistocene. Recent studies emphasized the problematics of interpreting low (<5 pmc) ^{14}C activities into groundwater ages, due to potential contamination sources, and provoked question for the real age of the aquifer. In the present study we used ^{81}Kr, with longer half-life ($t_{1/2}$=229,000 years), in order to extend the dating range beyond the ^{14}C and to solve this hydrological enigma.

The ^{81}Kr data of the ancient water body below the Negev Desert indeed indicate that groundwater age is beyond the scope of ^{14}C. The ^{81}Kr ages range from relatively 'young' ages of 50,000 years (still, beyond ^{14}C capability) and up to more than 600,000, indicating that replenishment happened in several consecutive events rather than a single epoch. However, these old ages do not eliminate the possibility of mixing with a younger, ^{14}C active water component, that does replenished the aquifer and ´rejuvenated´ the groundwater age. Hence, samples were collected for a reassessment of ^{14}C by two different methods: (1) water samples (for DIC) and (2) gas samples (for gaseous CO_z extraction). Both methods revealed low ^{14}C activities (<1 pmc), indicating that groundwater in the Negev does not contain any significant fraction of young (<20,000 years) groundwater.

We combined the new ^{81}Kr results in the Negev Desert with recent ^{14}C data in Sinai, where higher ^{14}C activities were measured close to the aquifer's recharge area, for tracking the age evolution downstream. Spatial deviations in groundwater ages highlight the importance of mixing of several water bodies (with different ages) along the flow paths.

Code of abstract: T4.5.2
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.5. Groundwater resources evaluation and management under arid conditions

Azraq aquifer overexploitation lead to a global salinization: the use of borehole geophysical monitoring tools to enhance groundwater management (Jordan)

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KEY WORDS - Aquifer salinization – overexploitation – monitoring – sabkha - brackish water plume migration

ABSTRACT

With the multiplication of the groundwater abstraction points since the 60's, the groundwater flow system of the Azraq basin (Jordan, Middle-East), formerly regulated by the sabkha Qa'Al-Azraq, passed to an influenced regime. From the 60's to the 80's the groundwater flow direction was mostly influenced by the natural springs surrounding the sabkha Qa'Al-Azraq. Later, due to over-pumping around the Azraq depression and subsequent water level drop down, the springs achieved to dry up in 1993 and the groundwater flow direction became more dependent on the wells' abstraction. Consequently, groundwater originating from Qa'Al-Azraq became more able to move toward the new attraction points which are at first the large irrigated areas located East of Qa'Al-Azraq and the AWSA wellfield, North-West of Qa'Al-Azraq where 17 water wells, 200 m deep in average, are operated since the 80's and provided an excellent drinking water supplying Amman capital. Moreover, in recent years, considerable change of quality was detected in the water withdrawn from AWSA wells. Saltwater formerly confined at the center of the basin, beneath the Sabkha Qa'Al-Azraq, may have started to move in the direction of AWSA wellfield.

An immediate action is necessary to better assess the salinization risk of the aquifer and better understand the groundwater exchanges between the former oasis, presently totally dried, and the wellfield.

The action undertaken under this project, started in September 2014, is the implementation of three monitoring devices (GMD) able to measure in real time the aquifer's salinization process. These downhole geophysical tools used here relies on an innovative solution, already implemented to answer to coastal issues and tailored to answer to the Azraq's specific questions. The information provided by the monitoring devices, aggregated to the existing knowledge on the groundwater levels, seasonal recharge and volumes abstracted, helps in tracing the saltwater movements (in time and in space) and better assess the contamination risk of the drinking water wells. Thus, it has been found that two concomitant mechanisms are responsible for AWSA wellfield salinization:

1) At boreholes AWSA 14, AWSA 13, AWSA 10, AWSA 3, AWSA 2 and AWSA 1, the increases in conductivity were caused by salt of local origin near the boreholes. It may come from the layers of gypsum which may be present in the drilling sequences or be transported by faults network. Future logging realized inside these boreholes could give the final answer to this question.
2) Since 1994, the groundwater flow direction, which ran from North to South (i.e. from the AWSA catchment area toward Qa'a el Azraq), was reversed. Groundwater now flows toward the catchment area, as the reduced piezometric pressure created by the extraction boreholes constitutes the lowest point. The hydraulic gradient has increased, from 0.0002 in 1995 to 0.0013 in 2007. Interpolating the piezometric history of AWSA 7 through to 2016 enables us to estimate that the hydraulic gradient is now 0.002. Thus it allows a plume of brackish water coming from the South to migrate toward the catchment area. This brackish water plume is moving North at a velocity of 0,60 m per day in the central part of AWSA wellfield where the transmissivity are the highest. In 2016, conductivity in the central part of AWSA wellfield is above 2000 µS/cm. At the north and the east part of the wellfield, because transmissivity are lower, the brackish plume is not present yet. In these places conductivity is still under 1000 µS/cm but they tend to increase close to this regulatory EC value in Jordan. GMD measurement have shown that this brackish plume is only located in AWSA wellfield catchment area inside of the main reversed groundwater flow. It affects all B4 aquifer depths and it is aggravated by a shallow brackish flow inside the basalt layer during the recharge period.

According these two concurrent salinization mechanisms, AWSA well field mean conductivity rose from 553 µS/cm in 1984, to 877 µS/cm in 2004, to **1577 in 2016 µS/cm**. To reduce this high conductivity value before sending groundwater to the distribution pipe, since 2007, the operator choose to reduce borehole pumping flow rate at south of AWSA wellfield, where brackish plume is already there, and increase pumping flow rate at north. This pumping flow rate management enables water conductivity to be decreased by 18 %. **Thus in 2016, electrical conductivity of the distributed water is equal to 1298 µS/cm**. However, if the increase of pumping at north of AWSA well field is a short term solution to decrease EC by 18 %, it contributes to brackish plume migration towards the north. This migration, favored by the increase of pumping at north, is responsible for a speed-up of groundwater conductivity increase at AWSA well field. **Using the same borehole management that is followed during this two last years could lead to an electrical conductivity of the distributed water equal to 2000 µS/cm in 2022.**

To extend the lifespan of the Azraq wellfield it is recommended to implement some operative actions.

The objective could be twofold:

- Restrict the extension of the brackish water plume and prevent its migration to the northern wells
- Define operating rules able to concurrently preserve the water quality and make energy savings

To achieve these goals a four steps action plan is here discussed, going thru

- diagnostic of the existing wells and instrumentation,
- implementation of three additional GMD,
- improvement of wellfield management rules
- 3D Modeling.

Code of abstract: T4.5.3
Type of presentation: Oral presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.5. Groundwater resources evaluation and management under arid conditions

Groundwater Resource Directed Measures

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KEY WORDS - Delineation, Classification, Reserve Determination, Prioritization, Resource Quality Objectives, Aquifer Firm Yield Model, Well Field Model

ABSTRACT
Water is a natural resource and belongs to all people of South Africa. Sustainability, equity and efficiency are identified by the South African government as central guiding principles in the protection, use, development, conservation, management and control of water resources. These principles recognise the following: basic human needs for present and future generations; the need to protect water resources for use; the need to share water with neighbouring countries; the need to promote social and economic development through the use of water; and the need to establish suitable institutions in order to achieve the purpose of the National Water Act (Act No.36 of 1998).
The Groundwater Resource Directed Measures (GRDM) follows a logical sequence of steps to achieve the aforementioned goals. This sequence requires the delineation of integrated units of analysis consisting of individual resource units which is assigned a specific class based on the current status. Once classification is complete the reserve calculation is carried out protecting basic human needs and ecological water requirements. The resource units are then prioritized based on various factors e.g. importance to users, threat posed to users and ecological importance. The prioritization process receives input from existing datasets, experts and interested and affected parties through a public participation process. Appropriate resource quality objectives are then assigned to prioritized resource units against which the resource unit are measured.
This paper focus mainly on the methods applied in support of the GRDM process. Delineation is based on statistical analysis of borehole monitoring parameters and producing Voronoi diagrams which are combined in a linear fashion to produce regions of similar geohydrological responses. The reserve calculation is based on the results of an aquifer firm yield model on regional scale, specifically developed for this purpose. Prioritization is accomplished through a weighting and rating approach of applicable criteria. Finally, the resource quality objectives are set for both regional and local scale, based on the aquifer firm yield and a wellfield model. The use of protection zones as part of the resource quality objectives allows for a GIS evaluation of infringements where protection zones overlap.

Code of abstract: T4.5.4
Type of presentation: Poster presentation
Topic: T4. Groundwater Monitoring – New Approaches
Session: T4.5. Groundwater resources evaluation and management under arid conditions

Assessment of wavelet transform in estimation of evaporation in three different climates

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KEY WORDS - Artificial Neural Network, Climate, Evaporation, Wavelet Transform

ABSTRACT

Evaporation is one of the most important processes in meteorology and hydrology. It is necessary to develop approaches to estimate the evaporation rates. The main purpose of this investigation was to evaluate the wavelet transform models in estimation of evaporation in three different climates of Iran. The proposed wavelet- artificial neural network (WANN) and artificial neural network (ANN) models were developed to simulate daily evaporation data of Ahwaz Station with arid climate, Sari Station with per-humid climate and Hamedan Station with semi-arid climate. Temperature, relative humidity, and wind speed parameters were used as input. The results showed that in both arid and semi-arid climate, the WANN model was performed better than that the ANN did. The coefficients of determination (r) were 0.91 and 0.82 for Ahwaz and Hamedan and Normalized root mean square errors (NRMSE) for these stations were 0.26% and 0.27%, respectively. But in Sari Station with per-humid climate, the accuracy of ANN was more than that with WANN. The coefficient of determination and NRMSE values in ANN were 0.78 and 0.44 %, respectively, in contrast, the r and NRMSE values for WANN were 0.74 and 0.47%. Therefore, it can be concluded that evaporation can be successfully estimated using ANN and WANN models in different climates.

Code of abstract: T5.1.1
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Karst aquifer as one of the major global water sources - state of art and perspectives

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KEY WORDS - karstic aquifer, global use, water source, sustainability

ABSTRACT

Karst aquifers are one of the main water sources used in the world. Several sources including preliminary results of on-going WOKAM (World Karst Aquifer Map) project indicated that different types of karstified rocks crop out over approximately 15% of ice-free land. The main "karst countries", those with more than 1 x 10^6 km^2 of karst surface, are: Russia, USA, China and Canada. But, in ¼ of the total number of countries karstic rocks are either totally absent or have a minor extension.

Much more problematic is to make an assessment of current global karst water use. Although the exact figure on karst water utilisation cannot be provided, this article represents an attempt to make such an assessment and upgrade earlier data.

The biggest actual karstic waters consumer is China. It is estimated that approximately 150,000,000 Chinese citizens depend solely on the utilisation of karst aquifers. The second largest karst water consumer is the USA where about 50 million people, mostly from sparsely populated areas, depend on these sources. Although karst has no large extensions in India (3%) there are 106 administrative districts with exposed carbonate rocks, while 46 million of its citizens use karst water in their everyday lives. There are also more than 10 million people using karst waters in Iran, Mexico, Indonesia, Russia, France, Philippines, Turkey and Italy. In principle, karstic rocks and aquifer systems provide the largest springs and they are widely utilised as a source of drinking water supply, much more than well fields or other type of constructed water tapping structures.

Based on UN statistical sources, literature data, local experts' opinions and some approximations the number of karst waters consumers has been assessed in 2016 at about 678,000,000 or 9.16% of the world's population. This is almost twice less than what was previously estimated in some of the reports.

Although often problematic because of unstable discharge regimes and high vulnerability to pollution, in many countries and regions karst groundwater represents the main source of potable water supply. Still, engineering solutions are often required to ensure sustainable water supply and prevent negative consequences of groundwater over-extraction.

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Topic: T5. Groundwater in Karst Systems
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Development of a Freshwater Lens Assessment Protocol for Karst islands

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KEY WORDS - Karst, Water, Climate, Hydrogeologic, Sustainable

ABSTRACT
Karst Islands like those found in the Philippine Archipelago present extreme challenges for stakeholders to manage their water resources in a sustainable manner. Anthropogenic Climate Change, land development, point source pollution and increased population have all combined to alter the water balance on these fragile islands. Karst features, shallow depth to groundwater and the potential for dissolution, contribute greatly to these challenges. Combined, these factors pose an array of complex research challenges. A field reconnaissance, and semi-structured interviews were completed on Bantayan Island in 2016. Drawing upon current groundwater characterization practices the research posits a novel approach for these hydrogeologic environs. With the application of the Freshwater Lens Assessment Protocol (FLAP) credible output for the characterization of the islands groundwater resources will be determined and integrated into an Adaptive Water Resource Management framework, empowering stakeholders to make informed decisions on sustainable abstraction strategies.

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Topic: T5. Groundwater in Karst Systems
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Establishing Geo-scientific Zones Of Contribution To Karst Drinking Supply Springs

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KEY WORDS - Karst, springs, Zones of Contribution, dye-tracing

ABSTRACT

Karst limestone aquifers supply significant and important groundwater sources in Ireland. The Rathcroghan Uplands in County Roscommon is a karst limestone plateau, approximately 200 km^2 and 60–150 m above sea level. The Uplands generally receive 800 mm of rainfall per year and is characterised by sinking streams, swallow holes, turloughs, an absence of surface water courses and relatively large springs dotted around its lower-lying perimeter. These springs supply drinking water to Public and Group Water Schemes. Contamination of these springs is relatively common, and severe pollution incidents have occurred.

In order to protect the quality of the supplies it is important to establish the surface and subsurface catchment areas, or 'Zones of Contribution' (ZOC), within in which rainfall and potential contaminants may enter groundwater and move towards the source. These ZOCs provide an area in which to focus further investigation and implement protective measures to manage the groundwater quality and sustainable abstraction rates. Establishing ZOCs to these water supply springs has recently been carried out by Geological Survey Ireland.

Given the unpredictable nature of karst groundwater, particularly the direction of groundwater flow, establishing ZOCs requires specific techniques, significant resources, suitable antecedent weather conditions, and time. Dye tracing is one of the most important tools available to determine flow directions in such terrain. Multi-dye tracing investigations were carried out in 2015 and 2016 on and around the Rathcroghan Uplands. The results, which are of national significance, highlighted an intricate network of flow with some unexpected directions, and provided evidence for delineating a 'jigsaw puzzle' of abutting ZOCs across the entire Uplands.

This work has significantly advanced the conceptual understanding of the karst hydrogeology of the Rathcroghan Uplands and enabled geo-scientifically robust ZOCs to be defined for all of the water supply springs. The challenging pattern of ZOCs now requires the individuals who drink the water and farm the Uplands to manage the land as a single community.

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Topic: T5. Groundwater in Karst Systems
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Ground water characteristics of the Ljubljanica River recharge area, Slovenia

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KEY WORDS - ground water flow, karst spring, ponor, river cave, Ljubljanica

ABSTRACT
The Ljubljanica River is an important tributary of the Sava-Danube system. About 60 % of its 1800 km^2 large recharge area is underlain by carbonates with a typical karst drainage system, including poljes, ponors, karst springs and large river caves. The reaction of the system to the rain events is intense, with large fluctuations of ground water levels and flooding of poljes. The research presents the results of automatic ("continuous") measurements of ground water levels, temperatures and specific electric conductivity in practically all caves reaching ground water level, ponors and springs between the Planinsko Polje on the south, Logaško Polje on the west and springs of Ljubljanica River on the northeast. The interpretation is based on basic hydraulic principles, hydraulic numerical models and 3D geological model produced in Geomodeller™. The results indicate potential hydraulic connections between different stations and zones with high transmissivity and storage. Evident influence of some geological structures that control the flow is also recognised. Diurnal fluctuation of water temperatures during flood recession was used to assess the travel time between the successive points. The results will provide better insight into the flooding of Planinsko Polje as well as into the structure of the studied karst aquifer. Additionally, the basic experience based guidelines are presented on how and where to select the points of monitoring in karst caves.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Hydrogeological conceptualisation of Pinarbasi karst spring for an effective protection zone delineation

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KEY WORDS - hydrogeological conceptualisation, karst spring, protection zone

ABSTRACT
Domestic water needs of about 35 % of the population in Turkey are supplied from groundwater resources. Future projections reveal that 82 % of the population is expected to live in cities by 2050. Increase of population also elevates the stresses on groundwater quantity and quality unless effective measures such that delineation of protection zones for wells and springs utilized for drinking water supply are established and applied. Methods which do not consider the type of aquifer and dynamics of recharge-flow-storage-discharge cannot be applied straightforward for every aquifer system due to the fact that each groundwater system has its own specific characteristics. Regulations and standards currently effective in Turkey are generic as they describe protection zones based on "distances" from the spring and do not include specific hydrodynamics of aquifers. As a consequence, it is common to observe that effective protection has not been provided. Although, different approaches with different level of complexity exists and applied for wells, there is no a commonly used method suggested for springs. Whatever method is to be applied for delineation of protection zone hydrogeological conceptualization is the essential procedure. The Pinarbasi karst spring with a mean flow rate of 2.6 m^3/s, the main source for water supply for Malatya metropolitan city. Effective protection of this spring is essential because it supplies drinking water to more than 800,000 inhabitants. Paleozoic aged recrystallized limestone forms the karst aquifer and the spring issues at the contact with the underlying schists. The complex hydrogeological setting required detailed geological and karst morphological mapping, hydro-meteorological analyses, hydrochemical and isotopic evaluations and drilling. Water budget calculations have revealed that the catchment area of the karst spring extends beyond the topographic drainage area. A large reservoir behind a dam constructed at the adjacent basin was found to be in hydrological connection with the spring. The authors discuss and demonstrates the how the situation became even more complicated because protection of the spring water also depends of protection of the dam reservoir.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Managed aquifer recharge into a karst groundwater system at the Wala reservoir, Jordan

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KEY WORDS Karst, managed aquifer recharge, semi-arid climate, Jordan

ABSTRACT

Karst aquifers in the semi-arid Jordan region were overused in the past decades due to rapidly growing population and increasing water demand. Managed aquifer recharge (MAR) is a promising approach to balance the high variability in water availability by underground storage of surface water and recovery during dry periods. The hydraulic anisotropy and heterogeneity of karst aquifers represents a particular challenge for the application of MAR and requires a comprehensive investigation approach. This study focuses on flood water capturing at the Wala reservoir, recharge into a moderately karstified aquifer and its recovery at a 7 km downstream wellfield. Research questions address the long-term impact of reservoir infiltration on the karst aquifer and the recharge potential of the reservoir under changing hydrological conditions and increasing water demand. In addition, measures are searched to improve the performance of the MAR system and its protection. Geological and hydrogeological investigations showed an increase in groundwater availability due to an annual average infiltration of about 6.7 million cubic meters (2002-2012) and an intensified karstification along the wadi course. Therefore, the karst characteristic duality of flow and storage was simulated using a two-dimensional vertical groundwater flow model including zones of highly contrasting permeability and anisotropy. Scenarios indicate that periods of low inflow still recharge substantial amounts of water, but sedimentation in the reservoir led to a long-term decrease in infiltration. The correlation between rainfall and reservoir recharge and bacteria occurrences in groundwater identified rainfall events as a trigger for groundwater contamination. A tracer test proved the major infiltration pathway of contaminated surface water into the aquifer. Based on a vulnerability mapping and contamination risk assessment, a combined protection zone concept was developed, which considers the interaction of surface water and groundwater. The reduction of sedimentation and removal of sediments from the reservoir are high-priority measures, as well as an improved concept for operating the wellfield and the implementation of protection zones. The applied approach is transferable to similar MAR sites in karstic and semi-arid environments.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Critical Zone in China's karst area: a hydrogeological Perspective

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KEY WORDS Critical Zone, Karst, Hydrogeology, China

ABSTRACT

As a highly heterogeneous and biogeochemically active zone of rock, soil, water, air and living organisms, the critical zone is an important concept in holistic Earth surface science. The critical zone extends from the top of canopy layer down to the bottom of aquifer and includes various types of landscapes including karsts. Karst Critical Zones (KCZ) are characterized by six outstanding features: (1) carbonate rocks are involved in various geochemical processes and represent Earth's largest carbon reservoir; (2) reaction kinetics are fast resulting in sensitivity to surrounding environmental changes (climate and human activity); (3) pore spaces can be large (cave or conduit, underground stream, lake or pond); (4) a large range of both above and below ground biota exists, ranging from microbiota to macrobiota; (5) thicknesses can range from centimeters to kilometers with complex formation processes that occur over seconds to tens of thousands of years; (6) material and energy exchange rapidly and frequently between surface and subsurface. These characteristics mean that KCZ face threats from many environmental problems including pollution, global change, urban and population expansion, rocky desertification and groundwater exhaustion.

China's karst area critical zone can be divided into six regions with specific characteristics that controls responses to human-induced changes that are unique to each area. (1) One area is a humid-temperate KCZ which is characterised by temperate continental monsoon climate (annual precipitation of 400~700 mm and annual air-temperature of -4-8℃), surface flora of mixed coniferous broad-leaved forest and meadow, chernozem and dark-brown forest earth with rich organic matter, Paleozoic limestone and abundant recharge from allogenic water, and large caves. (2) A semi-arid KCZ hosts the features of warm-temperate continental monsoon climate (annual precipitation of 400~750 mm and annual air-temperature of 8-14℃), deciduous broad-leaved forest, brown earth and large area loess, Cambrian and Ordovician limestone, and large karst springs with catchment areas >1,000 km^2. (3) An arid KCZ is characterised by arid continental climate (annual precipitation of 200 mm and annual air-temperature of 0-16℃), bush and shrub, desertified soil or grey desert soil, large area desert, strong physical weathering, special landscape of high mountains alternate with huge inland basins, Paleozoic and Mesozoic limestone, weak development of surface karst, low water-yielding of karst aquifer, and unique evaporite karst. (4) The Tibetan plateau KCZ hosts the features of high average altitude of >4000m, unique plateau climate (low annual precipitation of <300 mm and low multi-annual air-temperature of -5℃), alpine meadow and steppe, meadow soil, widespread permafrost and thermokarst phenomenon, strong freeze-thaw weathering, Mesozoic limestone, rare karst springs with low discharge of <1m^3/s and abundant travertine and tufa. (5) The KCZ in East Asia monsoon area is characterised by abundant annual rainfall (>1200 mm), high annual air-temperature (>15℃), evergreen broad-leaf forest, lime earth and red earth, Paleozoic limestone, particular peak-forest and peak-cluster landscape, abundant underground streams or springs, numerous caves, thick vadose zone, drastic change of groundwater level following rainfall and intense human activities. (6) The KCZ in the Indian monsoon area hosts the features of relatively low annual rainfall (~1000 mm), higher annual air-temperature (15~20℃), high average altitude of >1000m (Yunnan-Guizhou Plateau), evergreen broad-leaf forest, monsoon forest and tropical forest, latosol, red earth and lime earth, high mountains and deep gorges, karst graben basin coupled with karst mountain landscape, underground streams or springs, numerous caves, ultra-thick vadose zone and intensive water-soil erosion.

Future KCZ research in China should be directed towards: (1) focusing on interface process involving air-water-soil-rock- organisms interaction and nutrient cycle; (2) establishing a series of long-term integrating observation sites *in situ* covering different KCZ type in China according to the suggestions of Critical Zone Observatory supported by NSF; (3) launching global correlation on KCZ and building a global observatory network and data share; and (4) developing coupled system models to reveal structure and function of KCZ evolution.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Importance of stable and reliable monitoring of karst aquifers in assessing CC impacts

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KEY WORDS karst, monitoring, climate change, WFD, Montenegro

ABSTRACT

The base of this paper is the research on the influence of Climate Change (CC) on behavior of karst aquifers. Therefore it is clear that lack of data can be a big obstacle for further research and decision making. One of the most important steps of water policy and management actions on the level of European Union, with the Water Framework Directive (WFD) in first line, is permanent and accurate monitoring. Exploration area is located in Montenegro which is the candidate state for EU membership, and which voluntarily accepted to follow the EU water regulations. More than 90% of all groundwater used for water supply come from karst aquifers. In karst terrains it is especially likely that irrelevant data, which can misrepresent aquifer conditions, will be obtained. Level of complexity of the karst aquifer systems is high and therefore it is important to carefully plan monitoring network, where the design of a monitoring system should be in a form of a research project. Current monitoring data of such important water resource in Montenegro is usually limited on short-term measurements of level and capacity of karst springs and wells. Series of observations rarely exceed 30 years, which is insufficient for estimation of CC impacts on groundwater in karst systems. Since the improvement of monitoring conditions has the main importance for further research, this paper will give the proposal for the next steps towards the stable and reliable monitoring of the karst aquifers in Montenegro.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Springs location and it is discharge changes in a border zone of the Roztocze and Lublin Upland, SE Poland

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KEYWORDS - spring discharge, neotectonic, Roztocze region, Lublin Upland

ABSTRACT

The abstract presents and analyses the location and discharge changes of 19 springs in the border zone of the Roztocze and Lublin Upland in SE Poland. Systematic (monthly) measurements of the discharge were performed in 2008-2015 in selected springs with yield rates exceeding 15 dm3·s-1. The study area is characterised by a low density of the river system, complex geological structure, and considerable depth of underground water. The mean discharge of the largest analysed springs is similar to that of mountain (Tatra) karst springs, which have the greatest discharge in Poland. The springs in the study area serve an essential role in determination of river water resources, particularly in upper river sections, as they supply nearly 100% of water flowing in periods without precipitation. The analysis of the conditions of water circulation and spring location was based on: geological, hydrogeological and meteorological data. These results show that the location of springs with the highest discharge is determined by tectonics, primarily by the major zones of discontinuity (dislocations) and accompanying faults and/or grabens. This complex discontinuity system includes tectonic blocks of various sizes and ranks. The results of a complex analysis of the tectonics of the area and lithostratigraphic features of rocks in relation to the spatial distribution of the springs indicates that springs with the highest discharge, particularly those recharged from the Late Cretaceous aquifer horizon, are located in the areas of intersection of the main dislocations by accompanying en echelon or transverse faults. Moreover, the springs are typically located in estuarine fragments of dry, asymmetric valleys. These springs are located at the foot of steep valley slopes resembling isostatic rebound of the fault wings. It was also found that springs draining Late Cretaceous rocks are characterised by a substantially higher discharge and dynamics than springs recharged from Neogene formations. Based on the spring discharge regime, three groups of outflows were distinguished; they differed in the rhythm and dynamics of seasonal and annual discharge changes.

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Topic: T5. Groundwater in Karst Systems
Session: T5.1. Sustainability of karst aquifer use – global and regional outlooks

Ground Water exploration in Tarshich-Lebanon using Audio Magnetolluric (AMT)

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KEY WORDS - Groundwater, Audio Magnetotelluric, Geologic Formations, Karst, Hydrogeology

ABSTRACT

Water is considered to be one of the most valuable resources in Lebanon. Recent studies have shown, however, that Lebanon will be facing water shortage in the upcoming years mainly due to population growth and the resulting demands on the quantity and quality of Lebanon's water resources. Many activities (e.g. deforestation, dams, irrigation, drainage canals, etc.) are negatively affecting the water cycle and thus indirectly disturbing and minimizing the possibilities for water replenishment. Studies using geophysical methods should be carried out in order to explore Lebanon's water resources. Unfortunately, no studies have been conducted in this area. A prolonged investigation of the deep fresh water aquifers was carried out using Audio Magnetotelluric (AMT) in an area (N: 33°52'12'' and E: 35°49'48'') located in Tarshish – Lebanon which is subject to 1280 mm of total annual precipitation. AMT determines the resistivity of the various underground rock or soil layers with depth, and thus enable to identify the possible existence of productive aquifers. First, the authors conducted a hydrologic and hydrogeological study on the geologic section of the area and interpreted the presence of four geologic formations: J6, C1, C2a and C2b. An analysis of the AMT data obtained from the site showed the presence of four layers which was consistent with the data obtained from the hydrogeological interpretation of the section. Based on this formation, it was determined that possible water presence in C2b and J6 (karst formation). Well is currently being drilled - preliminary results indicated the presence of water level in C2b – it is expected to complete the well in a month.

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Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Analysis of drainage boreholes functionality on PP Grančarevo anchor field

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KEY WORDS drainage boreholes, anchor field, karst, tracer test, 3D model

ABSTRACT

Analises of drainage (boreholes) network functionality on PP Grančarevo were performed for the purpose of drainage groundwater from anchor block as well as to relieve water pressure from the background karst aquifer to the limestone block. Production of drainage boreholes and the formation of such drainage system is carried out during construction of the dam itself when it was determined instability of large limestone block on the left and directly below the dam. The task of the new research carried out in 2015 god. was that a series of specific field research, as well as modeling the spatial analysis (3D physical modeling) gave a better insight into the functionality of the network of drainage boreholes. The drainage system consists of 26 horizontal boreholes with an inclination of + 3°, direction of 78° and lengths up to 60 m. For the analysis of such drainage system and its functionality were performed extensive experiments mark the groundwater in monitoring boreholes in the hinterland of anchor field experiments the injection of water to the boreholes, monitoring the functioning of the wider zone of karst area, detailed geodetic surveys of objects and karst phenomena, analysis of boreholes TV logging in order to define the degree of karstification and development of 3D hydrogeological model of the drainage system and its functioning. One of the main conclusions of these studies is that groundwater affecting the anchor field only in conditions of high and extremely high groundwater levels, while medium and low groundwater levels have no influence on the anchor block, or karsts aquifer. Drainage boreholes from DB-20 to the lowest row of boreholes DM-1 to DB-6 and further downstream towards the boreholes PD-1 to PD-6 are intersected by a number of local ruptures, cracks and karstification zone, and generally have good coverage for drainage purposes. After all, according field and models studies conclusion were that all drainage boreholes are functional on higher and lowerlevel, which is in complete connection and depending on the groundwater level position.

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Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Application of sequence stratigraphic surfaces in karst hydrogeology: a case study from the Lar Formation, Central Alborz, Iran

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KEY WORDS Karst, Sequence Stratigraphy, Dolomite, Central Alborz, Iran

ABSTRACT

Dams and reservoirs in carbonate rock areas are often affected by water losses related to karstified fractures and bedding planes. Such leakages and the flow pattern in karst aquifers can only be understand based on a sound geological conceptual model. We studied the Lar Formation (Oxfordian - Tithonian) near the Lar Dam in northern Iran, Central Alborz, using methods from sequence stratigraphy.

The sequences were established based on microfacies studies and the analysis of diagenetic processes. Microfacies studies conduct a humid ramp model. Six depositional sequences (third order cycle) based on eight microfacies types were identified, corresponding to middle ramp to basin sedimentary environments.

Digenetic processes have been detected with respect to channel porosity with middle to large size dolomites (saddle dolomite). Due to pure limestone, synsedimentary fractures and joints can be a suitable place for medium to large dolomite and diagenetic phenomena. The type and size of dolomite are important for understanding the sequences. Sequence boundaries (SB) and maximum flooding surfaces (MFS) were recognized based on the presence of rhombic dolomite and microfacies with high depth and permeability with respect to middle to large size dolomite, respectively. Dolomitic zones (mixed zone area, rhombic type) without presence of evaporate minerals confirm the karst events and sequence boundary. The meteoric dissolution below sequence boundary is a common event along sequences and forms blocky and other cements.

Along the studied succession, from MFS to early Highstand system tract (HST) permeability increases due to increasing fluid rate and increasing dolomite crystal size. This event is related to groundwater flow. Dolomites have a good potential for permeability due to low emergent threshold. In this condition, the cementation does not occur in maximum flooding surfaces and the porosity remains in an open system. The recognized MFS at the Upper Kimmeridgian and Lower Tithonian in the Lar succession cannot form a well-developed karst system because of the presence of planktonic foraminifera, radiolarian and chert nodules that reflect the highest water depth among the sequences. Such Silicified layers can prevent karstification and groundwater flow.

We conclude that sequence stratigraphy is a valuable approach to understand the spatial distribution of permeability and, consequently, to predict groundwater flow. In the study area, synsedimentary fractures, joints and tectonics related to the closure of Neo-Tethys affect the development of permeability and groundwater flow.

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Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Compendium of more than 140 years of hydrogeological research at the Danube-Aach System, Germany

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KEY WORDS Karst aquifer system, tracer test, sinking stream, karst spring, flow divergence

ABSTRACT
The Danube-Aach System in SW Germany is a world-famous karst aquifer system and of major importance for the evolution of concepts and methods in karst hydrogeology. The Danube River has its source in the crystalline Black Forest and loses water where it reaches karstified Upper Jurassic Limestone in the western part of the Swabian Alb, Germany's largest karst aquifer system. The water re-emerges at several springs further to the south, which are tributaries to the Rhine River. The Aach Spring is Germany's largest karst spring, with a mean discharge of 8.590 L/s. The linear distances between the major swallow holes and the Aach Spring range between 11,8 and 20,0 km.
On average, there is a complete loss of the Danube River on 136 days/year. In 1874, the complete loss was recorded for the first time. Since 1884, there is a continuous record of the river stage. 1921 was the driest year with 309 days of complete loss. Between 1873 and 1949, the average number of days/year increased from 0 to 212, which can be attributed to increasing karstification. This is arguably the most spectacular currently observable example world wide of a breakthrough of karstification. For the last decades, the yearly mean sinking rate which considers only days with partial loss is about 6,5 m^3/s, with maximum values during the summer months.
Since 1869, 41 tracer injections were carried out to characterize the Danube-Aach System. Among these are the first quantitative tracer test with sodium chloride (1877), the first tracer test with uranine (1877) and the first quantitative analysis of uranine (1958). The confirmed underground connections show both flow divergence (i.e., one injection point is connected to several springs) and flow concentration (i.e., several injections are all focused to one spring).
The average linear flow velocities between the two main swallow holes and the Aach Spring are 188 m/h for the first (western) swallow holes with a gradient of 14,5 ‰, and 146 m/h for the second (eastern) one with a gradient of 7,7 ‰. Depending on the hydrological conditions, there are significant variations of the mean flow velocity, from 76 m/h for low flow conditions, to 291 m/h during high flow.

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Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Extreme and record discharges of Ljubljanica karstic spring system (Slovenia)

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KEY WORDS extreme value theory, minimum discharges, maximum discharges, flooding ratio, karstification

ABSTRACT
Karstic springs are important hydrogeological phenomena. Some of them are globally representing largest existing springs with very high discharges. For majority of karstic springs large fluctuations are typical. One of the most important indicators of the level of karstification in the aquifer draining through the karstic spring is ratio between maximum (Q_{max}) and minimum discharges (Q_{min}). If the ratio is low karstification of the aquifer is not well developed and storage of the aquifer is relatively high, if the ratio is higher karst inside of the aquifer is well developed and storage of the aquifer low. In spite of its simplicity Q_{max}/Q_{min} ratio of spring discharges is subject to large errors and uncertainties. They are consequences of discharge measurements errors and of the outflow from the aquifer in relation to seasonally dependent infiltration (e.g. rainfall infiltration, snow thawing, etc.). Extreme discharges of karstic springs can be also physically limited due to the hydrogeological characteristics of the aquifer draining through the spring. The Q_{max}/Q_{min} ratio is not a fixed value but it has its own empirical distribution which characterise the aquifer draining through the spring. In the paper we are investigating statistical characteristics of annual extreme discharges (Q_{min} and Q_{max}) and their ratio Q_{max}/Q_{min} in the system of Ljubljanica karstic springs (central Slovenia) with the discharge record of more than 50 years. To the data we are applying extreme value theory as well as probability analysis of record values. Based on these results we have estimated empirical distribution of the Q_{max}/Q_{min}. We are discussing physical background for such distribution as well as its dependency on the random nature of input variables to the aquifer.

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Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Hydrogeological controls on hypogenic cave formation – case study from Budapest (Hungary)

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KEY WORDS: karst, groundwater hydraulics, gravity driven groundwater flow, faults, Budapest

ABSTRACT

The karst area of Budapest is in the focus of research interest because of its thermal water resources and the on-going hypogenic karstification processes at the boundary of unconfined and confined carbonates. Hydrogeological studies revealed differences between the Central (Rózsadomb area) and Southern (Gellért Hill area) natural discharge areas, which explain the different cave forming processes and the related cave patterns in these areas. Retrospective hydrogeological research showed strong structural control on the springs' locations. Geochemical studies identified different temperature and geochemical composition of the discharging waters. With the aid of radionuclides the one and two-component discharge distribution was revealed. Recent hydraulic evaluation of the flow systems based on the complex analysis of real, i.e. measured, archival hydraulic data of wells explained these differences. This analysis resulted in a transparent, regional flow pattern representing gravitational flow systems in a topographically and geologically complex area built-up by confined and unconfined carbonates, which proved to be hydraulically continuous. Barrier faults, as well as vertically- conduit but transversally barrier faults, and aquitard units, proved to be effective obstacles for lateral flows, and responsible for the differences in the discharge distribution (one- and two-components) between the Central (Rózsadomb area) and Southern (Gellért Hill area) systems. Regarding the on-going hypogenic karstification processes, regional upward flow conditions were confirmed along the main discharge zone of the Danube. The cave forming process and the related cave patterns clearly reflect these differences, namely the two component discharge distribution allows for mixing corrosion and structurally controlled cave pattern. Whereas one component discharge resulted in microbially mediated sulfuric acid speleogenesis and water-table related caves.
The Hungarian Scientific Research Fund (OTKA) provided financial support to the project under the grant agreement no. NK 101356.

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Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Identifying flow dynamics and solute transport in a high karst plateau using tracer tests – a case study of the Javorniki – Snežnik karst massif (Slovenia)

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KEY WORDS high karst plateau, unsaturated zone, conduit flow, tracer test

ABSTRACT
High karst plateaus hold important groundwater resources which are increasingly threatened by numerous environmental problems such as climate change, contamination and overuse. To better protect and manage them, deepening of profound knowledge about flow and storage mechanisms is necessary. Tracer tests present an appropriate technique for studying recharge and transport properties of water and/or contaminant flow. In high karst plateaus they are usually less frequently applied. Namely, such aquifers are often several hundreds of km^2 large, have complex hydrogeological structure and supply several springs. Recharge mechanisms are conditioned by the orography, meteorological settings, and great hydraulic gradients. Groundwater flow and storage processes are often dominated by several hundreds of meters thick unsaturated zone and are highly dependent on respective hydrological conditions that may cause fluctuations of groundwater several tens of metres and flow velocities variations by several orders of magnitude. Therefore, the organisation of tracer tests is a difficult challenge. They are costly and long-lasting, the information acquisition is often very difficult or limited and strong tailing effects in the tracer breakthrough can be expected. In the respect of the above mentioned problems the present study focuses on the Javorniki – Snežnik high karst massif in SW Slovenia. The aquifer is drained toward several karst springs which belong to the Black or the Adriatic Sea basin, respectively. The uranine was injected into a shaft at the altitude 1014 m and 11 springs at the altitudes from 350 to 600 m asl were sampled, the most important among them in the period of 18 months. The results were compared with the findings of some previous tracer tests and provided new information on groundwater flow, estimation of the influence of a deep unsaturated zone on solute transport processes, and more accurate delineation of the main watershed between the two sea basins.

Code of abstract: T5.2.7
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Main hydraulic features of the upwelling water flux feeding karst springs

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KEYWORDS: karst, upwelling flux, hydraulic head, Southern Italy

ABSTRACT

Many springs are fed by powerful ascendant fluxes connected to specific hydrogeological conditions of aquifers. In karst environments, this phenomenon can have a huge extension, as karst aquifers are able to concentrate the drainage of wide catchment in single points (springs).
The most important hydraulic parameter of this phenomenon appears to be the (ascendant) hydraulic gradient of the flow, which is difficult to measure. In the Serino spring area (Southern Italy), thanks to deep piezometers into alluvial deposits covering a karst substratum, the ascendant flow has been detected, and then quantified. This has allowed us to estimate the hydraulic behavior of the aquifer under high and low flow, in terms of hydraulic head variation, and provided a new hydrogeological model explaining the hydrogeology of the Serino springs.
Under the ascendant water flux and after the excavation of a drainage tunnel, analytical solutions have been found to estimate the influenced zone of the aquifer; under low ascendant hydraulic gradient, a wider influenced zone has been found. During the high flow periods, the influenced area reduces, contrarily as observed during the pumping into wells.
The concentration of ^{222}Rn (radon isotope) increases during high flow periods, providing further relevant information on the upwelling flow in this karst area.
The results found in the Serino Spring area, are useful to understand also the hydraulic behavior of other karst springs.

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Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

RECHARGE TO THE KARSTIC EDWARDS AQUIFER

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KEY WORDS: Edwards Aquifer, recharge, dye tracing, stream gauging, prediction

ABSTRACT

The Edwards Aquifer hosts unique ecosystems and supplies drinking water to over 2 million people in central Texas, an area of rapid population growth. Although the basics of the aquifer system have been well understood for over a century, details and unexpected sources of recharge have emerged in the past several decades. The most important source of recharge is from the major losing streams/rivers that flow over the aquifer recharge (outcrop) zone followed by direct recharge from precipitation on the recharge zone. Major discharge is the large springs, which led to the siting of major cities, and more recently from pumpage. Early recharge estimates were from limited stream gauging mass balances, which led to underestimation of direct recharge as a small % of annual precipitation.

Since then, dye tracing has shown significant discharge to major streams that had not been considered and significant cross-formational recharge from the underlying Trinity Aquifer, especially where faulting has created lateral connectivity.

New detailed stream gauging has shown that losing stream zones are not uniform and can change both temporally and spatially, which complicates recharge calculation from the major losing streams.

DIrect recharge from precipitation on the aquifer rock outcrops has been measured using Bowen ratios and eddy covariance. This is dependent upon precipitation patterns and can vary from insignificant during dry times to an average of about 30% of annual precipitation resulting in direct recharge to the aquifer.

Other, generally smaller, recharge sources must also be considered. These include:

1) the effects of urbanization – water losses from water distribution and sewer systems and irrigation of parks and lawns averages 5% of total recharge in the urbanizing areas. These sources become more significant in times of drought.

2) planned artificial recharge – this includes diversion of streamflow to sinkholes outside the stream channel and structures within the streambed.

3) recharge from smaller, generally ungauged streams – these flow over aquifer recharge zones, but have not been adequately considered in the calculation of losing streams. These stream losses are small compared to the major streams, but are not insignificant.

4) recharge between segments when drainage divides disappear. For instance, during droughts drainage divides between different segments of the aquifer can disappear and discharge from one segment recharges the other.

Considering possible climate change and predictions population growth and increasing water demands over the Edwards Aquifer, estimation of its sustainable yield requires accurate estimation of recharge to the aquifer and prediction of future water budgets.

Code of abstract: T5.2.9
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Use of artificial and natural tracers to identify groundwater flow components in a high-alpine karst system (Dolomites, Italy)

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KEY WORDS alpine hydrogeology, tracer tests, residence time, stable isotopes, dolomites

ABSTRACT

The Alps are known as “the water tower of Europe” since many cities rely on drinking water deriving from this region, even far beyond the foot of the mountains. Despite the richness of water resources, due to the wide diversity of flow and transport processes controlling the groundwater flow, there are still very few conceptual and experimental studies regarding high-alpine aquifers. Artificial and natural tracers were combined to acquire knowledge on the characteristics of an alpine mountain region located in the Italian Eastern Alps, the Pale di San Martino Mountain Group. Uranine was injected in a karst plateau (mean elevation 2,600 m a.s.l.) and was monitored at the main springs outflowing at the base of the dolomitic massif. The parameters obtained from the elaboration of the tracer BTCs indicate a rapid flow component in the karst conduits (up to a mean tracer velocity of over 100 m/h), typical of highly karstified aquifers. Results from artificial tracer tests revealed the hydraulic connection between springs located very distant from each other (over 9 km) and at different altitudes. In addition to the artificial tracer tests, during which only preferential flow paths are considered, stable isotopes were used as natural tracers to investigate the slower flow component of the aquifer in the fractured network. A two-year monitoring of stable isotopes in meteoric waters and in spring waters was performed at the regional scale. Seasonal variations of the stable isotopes show a damped signal compared to the meteoric input and thus indicate a mixing of the newly infiltrated water with pre-stored groundwater. The seasonal variation of the δ18O in the monitored springs ranges between 0.6 ‰ and 2.0 ‰, indicating residence times of several months. The use of different tracer methods highlighted the presence of two flow components in the karst aquifer, a rapid flow component in the karst conduits and a slower component that contributes to the base flow of the main springs and ensures groundwater discharge even during drought periods.

Code of abstract: T5.2.10
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Monitoring and usage of natural and artificial tracers in the study of karst aquifers – a case study of the Malenščica karst spring, Slovenia

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KEY WORDS karst aquifer, natural and artificial tracers, monitoring, sampling, database.

ABSTRACT

Due to the highly heterogeneous structure of karst aquifers, the nature of groundwater flow and transport of matter is different if compared to the intergranular or fractured aquifers. Great variability of these characteristics in space and time is typical as well. Understanding the dynamics and dimensions of hydrological variability requires adequately adapted research techniques. Tracing natural and artificial tracers rank among very effective and commonly used hydrogeological methods. These comprise monitoring physio-chemical properties of water, which may vary in response to recharge event within a range of time intervals, including very short time spans. Therefore, monitoring in short intervals (e.g. hourly or even shorter) is recommendable. As much different points of the karst system as possible (sinking and underground streams, springs), including precipitation, should be included in the monitoring network. A parallel use of artificial tracers enables studying groundwater flow characteristics and transport of matter in selected parts of the aquifer. The experience in planning, setting up and maintenance of a comprehensive monitoring network are presented in this paper. These include access and work in demanding environments, as well as selection of tracer injections, monitoring and sampling modes and frequency. A dense monitoring network has been set up in the catchment of the Malenščica karst spring in SW Slovenia, which is drained by almost 750 km^2 large binary karst system of a complex structure of sinking rivers. Automatic dataloggers measuring water level, temperature and electrical conductivity have been installed at 5 springs, 5 sinking and 5 underground streams. Additional 3 ombrometers for measuring precipitation have been employed. In the study area, several multi-tracer tests with different injection points and modes have been executed. The established bulky database enabled analysis of its appropriateness and usefulness in karst aquifers studies.

Code of abstract: T5.2.11
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Transmissivity of Aquifer by Capture Zone Method: An Application in the Sete Lagoas Karst Aquifer, MG, Brazil

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KEY WORDS - Transmissivity, capture zone, aquifer test, karst, Brazil

ABSTRACT

Transmissivity is an important hydraulic parameter to determine the amount of water passed horizontally across a given saturated thickness of an aquifer. The techniques to quantify this parameter, such as grain size analyses or pumping tests, can have limitations of time/spatial scale, viability, or economically. One technique that can be used, but little adopted, is the capture zone analysis. In this study, capture zone analytical equations were used to estimate transmissivity values in order to verify the effectiveness of this methodology as alternative in situations where other traditional methods present implementation difficulties. The results were compared with field data estimated by aquifer tests conducted in the same region. A sensitivity analysis was also performed to identify possible discrepancies between the analytical and field data results. The aquifer studied was the Sete Lagoas Karst Aquifer in the urban region of the municipality of Sete Lagoas, Brazil. The method proved to be a viable and economical tool, where the analytical values compared to the aquifer tests showed similarities, being confirmed by a sensitivity analysis. However, a reliable potentiometric surface map, which enables the identification of the parameters for analytical capture zone equations, is needed.

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Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

A permanent karst drainage system developed over a diffuse-flow system in the same carbonate aquifer (Nerja, Spain)

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KEY WORDS - Carbonate aquifer, karst spring, caves, heterogeneity, Nerja

ABSTRACT
Vertical heterogeneity in the hydraulic conductivity (K) is a typical hydrogeological feature of karstic environments. In our study case, located at less than 1 km from the Mediterranean Sea in South Spain, this can be the outcome of the evolution in the development of nearly horizontal karst conduit networks associated to neotectonic uplifting. The studied aquifer (Las Alberquillas) is made up of densely fissured Triassic marbles, with more or less karstification depending on the particular location, and hosts various cavities, one of them is a show cave of particular significance (the Nerja Cave). It is known that local vertical interconnection between superposed karst networks can generate during periods of high flow the sporadic operation of inactive conduits giving rise to "trop-plein" outflows located at a higher altitude than the main discharge point. Here we report a case where on top (20-40 m) of a carbonate diffuse-flow regional system, with low values of K in the fissured rock matrix, there is a well-developed conduit-flow system. Unlike typical "trop-plein" schemes, the conduit-flow system gives rise here to a permanent spring –the Maro spring- with a typical karstic discharge: minimum flow in the 10 to 100 $L \cdot s^{-1}$ range, but peaks approaching 2000 $L \cdot s^{-1}$. Additional information from boreholes and from various geophysical techniques in the study area illustrates on the spatial patterns of void distribution in the karstic system, where small-scale perched groundwater levels have also been identified. There also exist hydrochemical and stable isotopes differences between the water from the two types of flow systems described. Overall, the case reported here can be an example of a large-scale perched groundwater level in carbonate terrains.

Code of abstract: T5.2.13
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

Analysis of recharge processes in karst systems

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KEYWORDS: endhoreic areas, recharge coefficient, karst massif, Italy

ABSTRACT
The recharge processes have been evaluated for several main karst massifs of southern Italy, Mt. Terminio, Mt. Cervialto and Matese massifs, characterized by wide endorheic areas. This paper highlights the contribute to springs discharge of open areas, closed areas and total catchment area of these massifs. The annual means recharge has been estimated by GIS tools, from regression of annual mean values of different ground-elevated rain gauges and thermometers. The recharge has been distinguished for endorheic areas and the other areas of springs catchment, and the ratio between the output spring and input rainfall has been also estimated (recharge coefficient). The annual recharge has been used to calibrate a daily scale model, which allows to estimate the amount of effective rainfall, which is retained as soil moisture; the amount reaching the water table (recharge s.s.) and the amount of rainfall which develops the runoff and leaves the catchment. All these amount vary through the hydrological year, in function of soil moisture deficit and daily rainfall intensity. When soil moisture reaches the field capacity, daily rainfall exceeding a specific threshold values (for Cervialto, Termnio, and Matese Massifs), develops runoff; the runoff amount increases during wet year and reduces during dry years, highlighting the important role of the endorheic areas mainly during wet years. Cervialto massif can be considered as a pure climate controlled aquifer, Terminio massif is moderately conditioned by groundwater abstraction and Matese massif is strongly conditioned by hydroelectrical exploitation. The model provided in this paper allows to define the recharge conditions through the hydrological year representing then a useful tool for water management.

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Topic: T5. Groundwater in Karst Systems
Session: T5.2. Functionality and control of groundwater flow in karst

THRESHOLD-CONTROLLED HYDRAULIC BEHAVIOUR OF A MANTLED KARST SYSTEM (TUHALA KARST AREA, NORTH ESTONIA)

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KEY WORDS: mantled karst system, shallow carbonate aquifer, monitoring, tracer test, overflow threshold.

ABSTRACT
The Silurian-Ordovician aquifer system, composed of diverse carbonate aquifers, is an important source of drinking water in the northern Estonia. It also comprises the shallow Nabala-Rakvere aquifer, a locally important source of groundwater that underlies the Tuhala karst area (TKA). The allogenic Tuhala river drains humic-rich water from a bog watershed and recharges the mantled TKA karst system that is hosted by the Nabala-Rakvere aquifer. The TKA system, covering approximately 188 ha, is discharged by two main groups of perennial and intermittent springs among which is the widely known overflowing spring, the Witch's Well. The aim of this study was to enhance understanding of the hydraulic behaviour and hydrodynamic properties of the TKA system in order to develop measures for the sustainable management of the aquifer in the future. A combined approach consisting of field observations, hydrometrical and physicochemical monitoring and tracer tests was applied. From October 2014 to December 2016, twenty-three surface- and groundwater monitoring points were observed for water level and physicochemical parameters and four quantitative groundwater tracer tests were conducted. The results show that a strong hydraulic link exists, primarily through well-developed conduits between the recharge and discharge area of the karst system. Depending on the hydrological conditions, groundwater flow directions and maximum velocities range between 225 and 800 m/h. A threshold-controlled throughput capacity and interaction with the adjacent aquifer cause imbalances between the input and output discharges of the karst system. Tracer tests coupled with surface and groundwater level relation curve analysis made it possible to divide three distinct stages with differing hydrodynamic characteristics in TKA. The identified thresholds help to specify the discharge conditions of the intermittent spring group and the overflow conditions of the Witch's Well.

Code of abstract: T5.3.1
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Comparison of pipe network and hybrid numerical models applied to karst systems in Ireland

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KEY WORDS - Karst, Modelling, Hybrid approach, Discrete conduit network modelling, Ireland

ABSTRACT

A model of a lowland karst network fed by allogenic runoff has been previously developed using a pipe network model (Gill, 2013). This model showed its ability to correctly simulate the hydrologic behavior of several studied karst systems in Ireland, especially regarding some specificities of Irish hydrogeology: water table close to the sea-level, ephemeral lakes connected to karst systems (turloughs), suspected secondary deeper conduits, and submarine/intertidal coastal springs. In this model, the groundwater-surface water interaction of the ephemeral lakes (known locally as *turloughs*) are represented as dimensioned ponds, whilst the contribution to the karst network from diffuse flow through the epikarst via the matrix and fracture flow has also been modeled using a combination of an infiltration module and network of permeable pipes. In this study we compare the ability of this pipe network model and of a distributed numerical model (a new version of MODFLOW-USG with Connected Linear Network module) to reproduce the flow dynamics of selected karst systems. The first karst catchment, located in County Leitrim, is very reactive. It was selected to compare the behavior of the two models in relation to conduit dominated systems. The second catchment, located in the County Mayo, has a slower response, and was chosen to assess the ability of both models to simlalte a higher component of diffuse recharge. The final models have been calibrated against four separate hydrological years. The results support the choice of both approaches depending on the complexity and the dominant hydrologic behavior of the studied system, and the presence of specific karstic features: the pipe network appears to be more adapted to simulate the complex groundwater/surface flows interactions, while MODFLOW-USG-CLNS provides a more accurate 3D characterization of the system regarding piezometric data.

Code of abstract: T5.3.2
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Damped tidal signal at an inland ephemeral lake (turlough) used to infer karst conduit connection

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KEY WORDS karst, inter-tidal spring, turlough, conduit, analytical solution

ABSTRACT
This research has used continuous water level measurements in a groundwater-fed ephemeral lake (or *turlough*) in a linked lowland karst network of south Galway in Ireland over a 3 year period in order to elucidate the hydrogeological controls and conduit configuration forming the flooded karstic hydraulic system beneath the ground. The main spring outflow from this network discharges below mean sea level making it difficult to determine the hydraulic nature of the network using traditional rainfall–spring flow cross analysis, as has been done in many other studies on karst systems. However, the localised groundwater–surface water interaction (i.e. the turlough) in this flooded lowland karst system can yield information about the nature of the hydraulic connections beneath the ground. Frequency analysis of the water level field data in the closest turlough to the sea was first carried out, using Fast Fourier transform analysis and as well as both discrete and continuous wavelet analyses, which clearly shows a the tidal influence on the water level at shallow depths, despite being located 8 km from the main spring outfall at the sea. An analytical solution of a simple conceptual model of a single conduit linking the turlough to the main spring was then developed. Using the two time series (turlough water level and tidal fluctuation) this showed that the turlough response is essentially in phase with the fortnightly tidal oscillation (with a much reduced amplitude) but exactly out of phase with the semi-diurnal tidal oscillation. This has then led to a modified conceptual model which includes an intervening large phreatic cave system beneath the ground located somewhere between the turlough and the sea which is required to promote the significant phase lag observed in the semi-diurnal field data. It is known that significant large caves do indeed exist behind the inter-tidal springs, although it has never been possible to access them. Hence, this study demonstrates the usefulness of such an elegant analytical modelling approach to such karst network investigations.

Code of abstract: T5.3.3
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Modeling water fluxes and storages in an Alpine karst catchment in the context of climate change

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KEY WORDS - Alpine karst, water fluxes and storages, climate change, numerical model

ABSTRACT
Climate change projections indicate significant changes to precipitation and temperature regimes in European karst regions. Alpine karst systems can be especially vulnerable under changing hydro-meteorological conditions since snowmelt in mountainous environments – itself highly sensitive to varying climatic conditions – is an important controlling process for aquifer recharge. Our study investigates water fluxes and storages within an Alpine karst catchment (Hochifen-Gottesacker, Austro-German Alps) using a distributed numerical model under historical and potential future climate conditions. Simulation results show that a large portion of precipitation infiltrates in the karst aquifer as autogenic recharge and contributes to surface runoff in the adjacent non-karst area, which can partly infiltrate into the karst aquifer as allogenic point recharge later on. Our simulations indicate that snow storage is dominant from November to April, while subsurface water storage in the karst aquifer dominates from May to October. The widely-used delta approach, guided by projected future climate conditions for the study region, was used to assess the potential impacts of climate change. The scenario runs revealed that variability in climate conditions significantly affects the spatiotemporal distribution of water fluxes and storages. Specifically they showed that: 1) The total catchment discharge decreases under all evaluated future climate conditions. 2) The spatiotemporal discharge pattern is strongly controlled by temperature variations, which can shift the seasonal snowmelt pattern. The snow storage capacity in the cold season (December to April) decreases significantly under all change scenarios. 3) Increased karst aquifer recharge in winter and spring, and decreased recharge in summer and autumn, partly compensate each other. 4) The impact of potential climate change on the subsurface flow dynamics is controlled by the unique hydrogeological characteristics of the karst aquifer. Overall, our study suggests that bespoke hydrological models tailored to the specific subsurface characteristics of a alpine karst catchment are needed to understand climate change impact.

Code of abstract: T5.3.4
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

On the value of water quality observations for karst model parameterization

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KEY WORDS karst water resources, karst modeling, model calibration, water quality data

ABSTRACT
If properly applied, karst hydrological models are a valuable tool for karst water resources management. If they are able to reproduce the relevant flow and storage processes of a karst system, they can be used for prediction of water resources availability when climate or land use are expected to change. A common challenge to apply karst simulation models is the limited availability of observations to identify their model parameters. In this study, we quantify the value of information added to parameter estimation when water quality data (NO_3 and SO_4) is used in addition to discharge observations to estimate the parameters of a process-based karst simulation model at a test site in Southern Spain. We use a three-step procedure (1) to confine an initial sample of 500,000 model parameter sets, (2) to identify alterations of individual model parameters through the confinement, and (3) to quantify the strength of the confinement for each of the model parameters. The last step allows us to quantify the information content of hydrodynamic and water quality observations for model parameter estimation. Our results show that NO_3 provides most information to identify the model parameters controlling soil and epikarst dynamics, while discharge observations provide most information about the recharge area and the groundwater dynamics. SO_4 mostly contributes to the identification of recharge processes. Looking at different flow states of the system, we also find that information provided by our observations varies over time.

Code of abstract: T5.3.5
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Quantifying surface water- groundwater interactions in a karst basin using the diffusive wave model

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KEY WORDS Flood routing; Lateral flows; Surface/groundwater interactions; Karst; Inverse model

ABSTRACT
In karst basins, flows in the hydrographic network are mainly controlled by surface water/groundwater (SW/GW) interactions. These interactions are mostly studied in streams during low water periods, but the question remains open when one needs to quantify them during flood events. The aim of this study is to investigate SW/GW interactions in a karstic stream using a flood routing model in order to improve the knowledge of the temporal distribution of lateral flows and to quantify them all along the year. For that, an inverse modelling approach using an analytical solution of the diffusive wave model accounting for lateral flows is applied on a karstic reach. The "inverse model" enables to calculate the lateral flow evolution using as input both discharge data from two successive gauging stations. The study site is the karstic reach of the Iton river in French Normandy (40 km), characterized by lateral outflows and inflows (losses and springs). The analysis of discharge-groundwater level relationships made it possible to identify the most correlated piezometers with baseflow. The discharge-discharge analysis at the flood event time scale shows that the peakflow attenuation in the stream decreases strongly when the piezometric levels are exceptionally high, highlighting a threshold effect from karst aquifer. To investigate SW/GW interactions during flood, lateral outflows were simulated for 33 flood events. We showed that the peakflow attenuation was the result of the combination of high flood wave diffusion in the stream channel but also of losses that increase when stream discharge increases. A last step consisted of simulating discharge at the downstream station knowing discharge at the upstream one and taking into account groundwater lateral flows modelled from piezometric levels. The good performance of the model confirms that diffusion is indeed the phenomenon that governs most of the flooding through the karstic zone. The influence of the stream losses is buffered by this phenomenon as well as by the drainage of the karst aquifer in the downstream zone of the basin. The new methodology proposed in this work opens challenging perspectives towards a modelling framework for the analysis of short time step lateral inflows/outflows in rivers leading to a better understanding of SW/GW interactions in karstic zones.

Code of abstract: T5.3.6
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Role-assessment of the soil-epikarst-unsaturated zone in the hydrogeological functioning of karst aquifers using a process-based simulation model

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KEY WORDS Karst aquifers · experimental methodologies · numerical modeling · integrated approach

ABSTRACT
Integration of information derived from different sources, characterizing techniques and modeling methodologies is crucial for extending the hydrogeological knowledge on karst aquifers and on its water resources availability. In this study, hydrogeological information and numerical simulations have been coupled in order to assess the role of the soil-epikarst-unsaturated zone and, to a lesser extent, of the saturated zone in the hydrogeological functioning of a small in size (6.3 km^2) but heterogeneous karst system in Southern Spain. Analysis of the natural responses (hydrodynamic, hydrothermal and hydrochemistry) of the water drained by two springs reflects the greater relative importance of the soil-epikarst-unsaturated zone in the hydrogeological functioning of the aquifer. These hydrogeological investigations have been the starting point for applying a process-based simulation model, which jointly considers data series of discharge, groundwater chemistry and natural tracers of infiltration from the rainfall and from the springs in model calibration. The VarKarst code is used to confine the spatial and temporal variability of recharge processes by defining distribution functions in model compartments. The calibration procedure allows assessing the role of the different zones in the hydrogeological behaviour, reproducing recharge variability and providing acceptable simulation results for the entire time series of available data. The integration of these quantitative results with previously (qualitative) inferred results from other experimental methodologies has supposed a significant advance in the knowledge on the behavior of the system, from which a realistic and robust conceptual model has been developed. The predictive value of an adequately calibrated numerical model makes it an excellent tool to planning the future management of water resources under uncertainty conditions. From this point of view, models can be useful instruments to evaluate the vulnerability of karst aquifers to the expected consequences of the climate change and to establish suitable adaptation strategies. This approach is, therefore, applicable to any hydrological setup and contains the potential to reveal deeper insights in any hydrological system with observations available.

Code of abstract: T5.3.7
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Investigating the relationship between rainfall and flooding within lowland karst wetlands by cross-correlation analysis

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KEY WORDS cross-correlation, karst, wetlands, turloughs, Ireland

ABSTRACT

Ephemeral groundwater-fed lakes (turloughs) form an integral part of lowland karst groundwater flow systems. The characteristic ecologies associated with the pattern of groundwater inundation are a highly-valued groundwaterdependent ecosystem type. Flooding within turloughs can also pose a significant flood hazard during extreme climatic events, and represents the principal form of groundwater flooding in Ireland. This study examined the relationship between flooding in these geographically-isolated wetlands and antecedent rainfall using cross-correlation. Hydrograph analysis using cross-correlation can provide valuable information on the internal structure and functioning of karst groundwater flow systems. The input signal comprised cumulative rainfall and effective rainfall time series summed over progressively longer durations. Further input series were generated using the Normalised Antecedent Precipitation Index (NAPI). The output was water level and volume time series monitored within 16 wetlands over a three-year period. Analyses were carried out using first the unprocessed data, then repeated following detrending to remove seasonal effects. A strong relationship was found between cumulative rainfall and wetland hydrology, with system memory effects ranging from the order of a few weeks to over six months. Results showed substantially improved correlation using both effective rainfall and NAPI series over the base rainfall series. This study provides strong evidence of the critical rainfall durations influencing wetland flooding, while also validating the basic conceptualisation of turloughs operating as recharge attenuation devices within the karst flow network.

Code of abstract: T5.3.8
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Karst water flow simulation and prediction in Daxing district, Beijing

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KEY WORDS: karst water, numerical simulation, available exploitation

ABSTRACT:
The shallow groundwater over pumping and pollution problems are keeping growing in Beijing, the deep groundwater has to be developed. Karst water is one of the most important deep groundwater in Beijing. Compared to regular groundwater, karst water has a deeper reserve and better quality. In Beijing, the main karst water is located in Daxing and Tongzhou district. The karst aquifer is beneath the quaternary aquifer. The depth of karst aquifer is usually deeper than 100m, consist of three main aquifers, they are Ordovician aquifer, Cambrain aquifer and Qingbaikouan aquifer. The recharge of karst water totally comes from the upper Quaternary aquifers, and the human exploiting is the main discharge. The boundary of karst aquifers has been proved as no flow boundary. The hydraulic conductivity were in the range of 1m/d to 15m/d. And there is no evidence showed that conduits have been existed in these areas.

In this study, the karst water flow has been treated as equivalent pore flow. According to the hydraulic conditions mentioned above, a three-dimensional heterogeneous vertical anisotropy karst water flow model has been built. The simulation results showed that the average recharge of the karst water system is $14425.74\times10^4 m^3/a$, and the allowable yield is $2309.36\times10^4 m^3/a$. Based on the identified model, four pumping plans have been proposed. Compared the four different exploiting schemes and analyzing the typical observation groundwater level curves and the budget of the aquifers, the best way to pump the karst water is keeping the current exploitation plan till 2020. After 2020, the Niantan karst water source in Daxing district should be completely closed. Then the karst water pumping can reach the exploitation and recharge balance step by step.

Code of abstract: T5.3.9
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Spring hydrograph and recession curve analysis in deep karst aquifer of Grand Canyon National Park, USA

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KEY WORDS - hydrograph, springs, recession, Grand Canyon

ABSTRACT
The Redwall-Muav aquifer (R aquifer) is a thick (up to 400m), well-developed karst system over 1,000m below the Kaibab Plateau of the north rim of Grand Canyon National Park. Precipitation on the rim infiltrates the subsurface through 1,000's of sinkholes, and travels vertically and horizontally through a separate, perched karst aquifer and several impermeable layers via faults and fractures. Transit time from infiltration to spring discharge can be rapid for summer monsoon events, due to large dissolved conduits in the karst. Winter snowmelt, which dominates the climate for the majority of the year, recharges the aquifer on a slower scale, and has a longer residence time than summer monsoonal precipitation.
Several R aquifer springs have recently been equipped with continuously recording transducers, which monitor stage and temperature. With manual discharge measurements, a stage-discharge rating curve can be used to create hydrographs for analysis. Most notable among these springs is Roaring Springs, the sole supply of potable water for both rims of Grand Canyon National Park, supplying over 6 million visitors annually. Other monitored springs include Angel Spring, Emmett Spring, Abyss Spring, and Tapeats Spring. Recession curves from monsoon and snowmelt events obtained from hydrographs separate the flow paths into conduit, fault/fracture, and/or matrix flow. Comparison of the hydrographs and precipitation response time reveals the properties of this complex, deep aquifer system in ways not previously possible. Results of this study will be essential to comprehensive management plans in Grand Canyon National Park and other karst aquifers to adequately protect groundwater and springs ecosystems.

Code of abstract: T5.3.10
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.3. Modelling of flow and contaminant transport in karst

Unravelling the hydraulic properties of the chalk in Limburg, the Netherlands, using artificial neural networks

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KEY WORDS chalk, Cretaceous, karst, hydraulic properties, artificial neural networks

ABSTRACT
Thick layers of unconsolidated Cenozoic deposits are present in large parts of the Netherlands. These deposits form important aquifers and aquitards and have been the main focus of hydrogeological research. In the eastern and southeastern most part of the Netherlands however consolidated Mesozoic deposits surface. In South-Limburg these deposits partly consist of Paleocene and Late Cretaceous chalk, the main aquifer in this area. The hydraulic properties of this aquifer are poorly understood.
Exposures of the chalk, especially in quarries, show that the upper part of the chalk is karstified. This together with flow measurements in wells have led to the assumption that hydraulic conductivity is high at the top and that it rapidly decreases with depth. For the national 3D hydrogeological model REGIS II five zones of varying thicknesses have been distinguished with hydraulic conductivities ranging from 100 to 0,01 m/d. The current approach however tends to overestimate hydraulic conductivity, especially in the northern part of South-Limburg where the chalk aquifer is covered by Cenozoic deposits. Apart from hydraulic conductivity varying with depth and the depth of the groundwater table other factors might be of importance that have not been considered so far, such as thickness of the Cenozoic cover layers, the geological formation, lateral facies changes within the chalk, vicinity of fault zones. Due to these many factors and the absence of a precise model combining all of these factors, research is being conducted to find out if artificial neural networks can be used to estimate better the hydraulic conductivity of the chalk aquifer. The neural network is trained by using the results of pumping and well tests as target data and the (hydro)geological information at these test sites as input data. It will be investigated whether the trained neural network gives improved results as compared to the current simple model overestimating hydraulic conductivity.

Code of abstract: T5.4.1
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.4. Protection of karst sources and environment

EPIK Intrinsic Groundwater Vulnerability Assessment and Statistical Sensitivity Analysis: Case Studies from Serbian Karst

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KEY WORDS - karst, EPIK, vulnerability, sensitivity analysis, Serbia

ABSTRACT
Water pollution of karst aquifer which is open and very permeable is major constrain in local water management. In order to facilitate development and protection of groundwater resources several methods for vulnerability mapping based on multiparameter system have been created. One of the very first is EPIK intrinsic groundwater vulnerability assessment method (Doerfliger & Zwahlen, 1995).The EPIK method that includes determination of epikarst (E parameter), protective cover (P), infiltration condition (I) and karst network development (K), was used to create vulnerability map for two distinct karst areas of Serbia: Suva planina Mt. in the Carpathian mountain chain (Eastern Serbia) and the Babine karst plateau, in the Dinaric Alps (Western Serbia).In order to determine the required parameters for the research areas a detailed geological survey was carried out, and data of lithology, karst features, precipitation, vegetation and soil cover, were gathered from various sources. A parameter-balance study and a sensitivity analysis were performed to evaluate the influence of single parameters on aquifer-vulnerability assessment. Research areas were taken into consideration in order to compare final results of analysis regarding: karst occurrence, type and level of karstification, degree of natural protection. A map of intrinsic vulnerability of the aquifer and of the local water-supply system shows existence of 4 highly vulnerable areas in both case studies. Further statistical sensitivity analysis (Map Removal Sensitivity) of Suva planina Mt. showed that the K parameter has the lowest sensitivity that implies the highest impact on the final vulnerability score. The same analysis for the other study area showed slightly different results. The lowest sensitivity has parameter E and the highest sensitivity has parameter P. Assessment of effective weighting factors showed that P parameter has the lowest effective weight in the karst area of Suva planina Mt and that parameter K has the lowest effective weight in the Babine karst plateau. As common, parameter I, which also reflects local vertical karstification intensity has the highest effective weight in both cases, thus has the highest impact on the final vulnerability score.

Code of abstract: T5.4.2
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.4. Protection of karst sources and environment

Karst Aquifer Vulnerabilty Assesment (KAVA) method on the example of two catchments in Croatia

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KEY WORDS karst aquifer, vulnerability assessment, KAVA method, Croatia

ABSTRACT
During 2013-2016, within the GEF UNEP/MAP and UNESCO-IHP's MedPartnership Project, a new method for assessing the intrinsic vulnerability of catchments and springs in karst terrains was developed. The Karst Aquifer Vulnerability Assessment (KAVA) method was developed based on the analysis of parameters and experience from the fieldwork and protection system of karst areas in Croatia.
For assessing of the intrinsic vulnerability of karst aquifers are used four basic factors: Overlay, Precipitation, Infiltration and Aquifer conditions. The overall result of the analysis is presented with two indices of vulnerability: SV index (source vulnerability index) – for karst springs vulnerability, and RV index (resource vulnerability index) – for karst aquifers vulnerability.
Within this paper will be presented results of using this method at two very complex karst sites in Croatia, one large and one small catchment. Both catchments belong to the Adriatic Sea catchment and have discharge at the northern coastal area of the Adriatic Sea.
The first site is the Novljanska Žrnovnica catchment, which is one of the largest karst catchment in Croatia. Part of this springing zone is fed from the Gorski kotar sinking zone, part from the mountain area in the hinterland of the main spring, and part from the Lika sinking area. The main spring Novljanska Žrnovnica is captured for the public water-supply. The second site is the Bakar Bay catchment area that occupies area of about 156 km2. This catchment area spreads from the discharge zone towards the mountain region of the Gorski kotar. However, in this discharge zone are captured even three springs for the public water supply. Water quality and quantity of these four springs are very important for the very wide coastal touristic area, especially during the tourist season.
Sanitary protection zones of these springs were defined, and the use of the intrinsic vulnerability mapping as the KAVA method can contribute to the groundwater protection as an additional data which should be used for updating of the protection zones.

Code of abstract: T5.4.3
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.4. Protection of karst sources and environment

Middle Risle critical zone observatory : monitoring karstic processes evolution in the river, their impacts on surface water/groundwater interaction and their consequences on aquatic ecosystems

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KEY WORDS surface/groundwater interactions, critical zone, karst, ecosystem, modelling

ABSTRACT

The Risle river, in its middle portion, is frequently affected by episodes of major sinkholes development; indeed, in the last decade or so, two major sinkholes developed in the river bed leading to crisis situation with a complete river loss in the underlying groundwater and a dried up river course over distances of several kilometers downstream during the summer season. This resulted in major modifications in hydrogeological and in surface – groundwater interaction processes, with major consequences on water quality, water uses and water dependent ecosystems.
To understand this phenomenon, its impact both on surface-groundwater interaction processes and on aquatic ecosystems and to improve crisis management, a multi-parameter monitoring program called the middle Risle critical zone observatory has been set up, in order to acquire the necessary data and knowledge and develop proper tools to best manage these situations. Several monitoring networks were implemented involving several partners. Exploratory tools and methodologies were also developed. The work carried out in this project notably included setting up monitoring networks for groundwater level, water river level, differential flow in rivers, temperature and conductivity surveys, springs yield, ecosystem surveys (fishes, macroinvertebrates, vegetation) as well as modelling surface, karst and groundwater flow…
Results obtained were numerous including river loss impacts on fishes, macroinvertebrates and vegetation and population recovery rates. Some vegetal species seem to be a reliable indicator for surface/groundwater interaction. The dynamics of local hydrogeological processes are assessed and linked to the consequences on the ecosystems habitats and on water use.
Inverse modelling using an analytical solution of the diffusive wave equation helped assessing for lateral flows during flood events, quantifying spatio-temporal variability for surface water and groundwater exchanges. It also highlighted the important role of the karstic zones both on storage and on river flood peak attenuation processes, thereby protecting downstream villages against floods.
Finally an approach using transfer model based on computing the convolution integral of up to several signals allowed building the first functional scheme of this karst system.

Code of abstract: T5.4.4
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.4. Protection of karst sources and environment

Vulnerability Mapping of Karst Aquifers in Qatar

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KEY WORDS - groundwater, vulnerability mapping, DRASTIC, EPIK, Qatar

ABSTRACT

Qatar is an arid country with limited natural water resources. Desalination plants meet domestic and industrial water demand, whilst farmers use groundwater for irrigation. The karst aquifer in the country is the only natural source of the precious fresh water, and it is highly overexploited.

The purpose of this study was to assess the vulnerability of aquifers in Qatar to contamination. Vulnerability mapping is very useful for groundwater protection and for on-land activities management such as locating of landfills and wastewater treatment plants. Vulnerability also helps design of groundwater monitoring networks. Several thematic maps, including hydrogeological settings, soil, water table, karst features and recharge, were prepared and manipulated within Geographical Information System (GIS). The final vulnerability map was obtained as a sum of different rated maps using Raster Calculator.
Two approached were followed; the DRASTIC vulnerability method and EPIK approach for karst aquifers. In DRASTIC approach, seven thematic weighted maps were prepared and summed up to produce the final vulnerability map. EPIK approach uses four weighted parameters, with more focus on karst geology. Both approaches produced similar results with some variations. Results showed that coastal areas and high fractured zones within the limestone have the highest vulnerability classes in both approaches. However, EPIK approach put higher weight on fractured limestone than the coastal areas.

Code of abstract: T5.5.1
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Urban impacts on the groundwater quality and quantity of a karst aquifer in Jordan

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KEY WORDS Urban hydrogeology, karst aquifer, semi-arid climate, intermittent water supply, groundwater contamination

ABSTRACT
Large areas in the Middle East consist of carbonate rocks, which constitute important karst aquifers that are vital for drinking water supply and agricultural irrigation. Rapid population growth and urbanization result in an increasing pressure on these groundwater resources in terms of both quantity and quality. We have studied the multifaceted urban impacts on a karst aquifer underneath the city of As Salt in Jordan, which is drained by several karst springs that are partly used for the water supply of the city, with the ultimate goal to achieve a better protection and management of this urban groundwater system. Key methods include high-resolution monitoring of discharge, chemical and microbiological water-quality parameters; stable-isotope analyses of nitrate and water; and analyses of X-ray contrast media and other pharmaceuticals. The monitoring results during the dry season have revealed consistently recurring weekly variations of discharge, nitrate and fecal bacteria at one of the karst springs draining this urban aquifer. These variations can be attributed to the intermittent water supply of the city, which is typical for semi-arid conditions. Leakages in freshwater mains were identified as the main cause for the observed variations. The isotopic studies allowed to quantify the contribution of city effluents from leaky networks and sewers to groundwater recharge, which ranges between 30 and 64 %. Monitoring for 25 different pharmaceuticals in 66 samples from this groundwater system reveled 91 % of positive detections. Interestingly, the former standard X-ray contrast medium diatrizoic acid was found more frequently in groundwater than in wastewater, at comparable concentration levels, while iopamidol, a more recent substitute, was detected at much higher concentrations in wastewater than in groundwater, which can be explained by changing prescription practices of these two X-ray contrast media. As a practical result of this study, water supply from the most contaminated spring was largely stopped, and relevant springs were equipped with early-warning systems for contamination. In conclusion, the remediation of both freshwater mains and the sewage network, as well as improved waste-water treatment, are the most urgent technical measures to improve the groundwater situation in this urban aquifer.

References:

Grimmeisen F, Lehmann MF, Liesch T, Goeppert N, Klinger J, Zopfi J, Goldscheider N (2017) Isotopic constraints on water source mixing, network leakage and contamination in an urban groundwater system. Science of the total environment. 583: 202-213.

Grimmeisen F, Zemann M, Goeppert N, Goldscheider N (2016) Weekly variations of discharge and groundwater quality caused by intermittent water supply in an urbanized karst catchment. Journal of Hydrology, 537: 157–170.

Zemann M, Wolf L, Grimmeisen F, Tiehm A, Klinger J, Hötzl H, Goldscheider N (2015) Tracking changing X-ray contrast media application to an urban-influenced karst aquifer in the Wadi Shueib, Jordan. Environmental Pollution 198: 133-143.

Code of abstract: T5.5.2
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Evolution of bacterial biofilms and chemical precipitates in thermal springs depending on flow kinetics (Buda Thermal Karst, Hungary)

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KEY WORDS bacterial biofilm, precipitate, thermal spring, Buda Thermal Karst, in situ experiment

ABSTRACT

Bacterial biofilms and chemical precipitates are known from several thermal springs, underwater caves and thermal wells all over the world. These were examined in the hypogene karst area of the Buda Thermal Karst (BTK), Hungary. The biofilms are dominantly formed by chemolithoautotrophic bacteria, they are usually filamentous and have low TOC content as they mainly consist of calcium, silica, iron and magnesium. Iron forms iron-oxyhydroxide compounds (goethite, ferryhidrite) which provide the red color and the high adsorption capacity of the biofilm. Though biofilms, precipitates and waters of natural spring caves were extensively studied by previous authors, their evolution in different subenvironments and their interaction with the water are not yet properly understood. Factors influencing the dominance of microbially induced processes or simple chemical precipitation are not very well studied either.

So the aim of our study was to follow the evolution of bacterial biofilms and chemical precipitates with the simultaneous monitoring of basic physicochemical parameters (temperature, specific electric conductivity, dissolved oxygen content, pH, flow velocity and/or volume discharge). With this end in view in situ experiments were executed at two different sites. The first one was running for a year in the quasi-stagnant Török Spring at the Gellért Hill, BTK. The second one was running for twelve weeks at the Gellért Tunnel, Gellért Hill, BTK, where thermal water was directed to flow in an artificial canal. At both sites, sterile glass slides were used as surfaces for precipitation. At Török Spring they were put in a test-tube rack into the pool of the spring, while at the tunnel the slides were laid into the canal at eight places in different distances from the outflow.

During the experiments the development of the biofilms and precipitates was tracked with electron microscopy. At the end of the experiments, the biofilms and precipitates were analyzed and compared on the basis of the results of XRD, SEM, ICP-MS, Mössbauer and gamma spectroscopy, $\delta^{34}S$ measurements and 16S rRNA gene sequencing.

The research was supported by the NK 101356 OTKA research grant and by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2.-15-2016-00009 'ICER'.

Code of abstract: T5.5.3
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Hydrogeochemistry of a karst aquifer affected by acid rain in SW China

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KEY WORDS - karst groundwater; hydrogeochemical characteristics; acid rain; carbon isotope

ABSTRACT
In karst area, geochemical characteristics of shallow groundwater are essential for environmental impact assessment and rock weathering study. Generally speaking, in carbonate areas, rock dissolution is mainly affected by CO_2. However, the low pH of precipitation in acid rain area influences the carbonate dissolution, and then has effects on chemistry of groundwater and $\delta^{13}C_{DIC}$ (carbon isotope of dissolved inorganic carbon, DIC). In recent 15 years, Chongqing, SW China was greatly suffered from acid rain with a pH value of between 3.8 and 4.5. Therefore sulphuric acid widely affects carbonate chemical weathering and karst hydrochemistry. Groundwater from Jiaoshi, Fuling, eastern Chongqing was sampled and analyzed for the hydrochemistry and carbon isotope in DIC. The result shows that the average pH is 7.8 and TDS ranges from 30 to 360 mg/L. The major hydrogeochemistry types are HCO_3-Ca and HCO_3-Ca·Mg owing to the carbonates dissolution in karst aquifers. A small part of samples is HCO_3·SO_4-Ca type, in which SO_4^{2-} is contributed by the acid rain. However, almost all groundwater samples satisfy with the National Drinking Water Standard. The $\delta^{13}C_{DIC}$ ranges from -12.5‰ to -10.8‰, which has been modified by DIC originating from the dissolution of carbonate by acid rain in the form of H_2SO_4 in the study area. The milligram equivalent ratio of $[Ca^{2+}+ Mg^{2+}]/[HCO_3^-]$ is between 1.09~1.77, suggesting sulfuric acid is essential to the chemistry and $\delta^{13}C_{DIC}$ of groundwater. Meanwhile, based on stoichiometric relationship, the average proportion of carbonate dissolution by sulfuric acid is 46% and the produced DIC account for 31% of the total DIC in groundwater. The result indicates that sulfuric acid has a significance effect on carbonate weathering in acid rain area, and then affects carbon source and sink.

Code of abstract: T5.5.4
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

The Role of Groundwater for Dissolved and Particulate Carbon Fluxes in a Small Karstic Stream: The Schwabach River, Bavaria, Germany

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KEY WORDS Stable isotopes, carbon cycling, rivers, global change,

ABSTRACT
Rivers situated in karst bedrock are known to emit more CO_2 than waters in granitic or sandstone terrains. Particularly for small streams, this is likely related to groundwater inputs from karst aquifers. Due to the abundance of karst terrains worldwide, these features play a crucial but as yet unclear role in the global carbon cycle. This lack of information is addressed by the present Marie Skłodowska-Curie Actions (MSCA) funded work, which combines stable carbon isotope determinations with flux estimates of dissolved and particulate riverine inorganic/organic carbon (DOC, DIC, POC) and pCO_2 estimations. It is one of only a handful of studies to simultaneously address DIC, DOC and POC dynamics with a high temporal resolution dataset, and will reduce uncertainties in the global carbon budget while clarifying linkages between groundwater-surface-water interaction and carbon cycling.

The study applies datasets of high sampling resolution with weekly and up to daily measurements. The studied river, named Schwabach, is located in northern Bavaria, Germany. It is a first order groundwater and spring-fed tributary within the Rhine River System and is emplaced in the prominent karst terrain of the Franconian Alb. Initial results indicate the dominance of DIC in fluvial carbon exports, followed by POC and DOC. The associated stable isotope data suggest that the DIC is derived from both geological (carbonate aquifers) and biological (soil-respired carbon) sources. DOC isotope patterns show signatures similar to C3 plant terrestrial carbon and those of POC are more ^{13}C-depleted relative to DOC. This likely indicates a more significant autochthonous component and a greater influence of aquatic biology. CO_2 estimations show values that are consistently elevated above ambient atmospheric concentrations, confirming that the Schwabach River is a net source of CO_2 to the atmosphere and an indirect avenue of groundwater CO_2 emissions. This research fills an important gap in the study of carbon cycling in karstic terrains, and provides more clarity on the role of such environments in the global carbon cycle.

Code of abstract: T5.5.5
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Tracking fecal contamination in karst groundwater

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KEY WORDS - Tracing experiment, microbes, cell count, source tracking, karst aquifers

ABSTRACT

Knowledge about the origin and fate of both natural and fecal microorganisms is crucial for predicting microbial contamination in karst groundwater as well as for establishing adequate protection measures. Conventional monitoring provides limited information in this context, as it records the arrival of fecal indicator organisms in an unspecified manner and fails in identifying contamination sources and quantifying potential attenuation.

In order to better control source conditions for the investigation of fecal input and transport, tracing experiments were conducted in the vadose and saturated zones of karst aquifers in Switzerland. These experiments employed a liquid manure injection, together with a conservative solute reference tracer. Diverse microbiological and physico-chemical parameters were analyzed for tracking fecal contamination and for comparing their differing behavior in the subsurface and impact on karst groundwater quality. The array of parameters also included the total microbial cell count, with microorganisms originating from fecal contamination representing only around 1/100'000 of the total bacterial load at karst springs.

Experimental results are discussed in terms of attenuation processes, storage and remobilization, as well as with respect to karst system vulnerability and spatial-temporal heterogeneities. They are compared to typical microbial signatures observed in karst groundwater and their changes over natural recharge events. This is particularly promising when integrating more detailed microbiological information into the assessment, such as the LNA/HNA and live/dead ratio of the cell count, or molecular markers for microbial source tracking. Such a toolbox of techniques – going beyond conventional fecal indicator bacteria analyses – allowed greater insight into the origin and fate of fecal contamination and provides the basis for reliable hypotheses regarding specific transport and attenuation processes.

Code of abstract: T5.5.6
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Artificial sweeteners: Sucralose and Acesulfame-K; emerging pollutants indicators of specific transport in karst systems: Application to semi-arid regions

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KEY WORDS karst, transport, emerging micropollutants

ABSTRACT
The assessment of vulnerability in karst system is highly challenging as it highly depends on the identification of diffuse and concentrated infiltration from surface karst features, the latter varying with time. This work shows that the artificial sweeteners Sucralose and Acesulfame-K can be used as transport indicators for persistent waste water effluent in karst systems.
In the framework of a PEER NSF/USAID funded project, a karst spring (Qachqouch; yearly discharge of circa 50 Mm^3) in Mount Lebanon was monitored following a multi-precipitation event. Acesulfame-K (ACE-K) and Sucralose (SUC), indicative of domestic waste water, Chloride and Calcium ions, Electrical conductivity (EC), and turbidity along with discharge were collected at the spring for nine days after the rain events at time intervals varying between 30 min and 4 hours. The samples were analyzed for ACE-K and SUC at Eaton Eurofins in California. A first sampling campaign was undertaken to assess the base flow concentrations in wells, waste water, and the main losing river on the catchment area along with Spring Qachqouch. It revealed that ACE-K and SUC are found in the spring at base flow concentrations of 170 ng/l, and 120 ng/l respectively.
A two-end mixing model based on Chloride and Calcium allowed the quantification of newly recharged water (11% of total flow) reaching the springs at specific monitoring intervals through fast flow pathways. The results revealed that the artificial sweeteners are persistent in the system outside rain events. They are mostly transported to the springs through fast pathways from flushed wastewater; their breakthrough curves coincide with the arrival of new waters (from the sinking stream or sinkholes) as portrayed by other indicator parameters such as turbidity. About 80 grams of SUC and ACE-K reached the springs during peak response in three consecutive events. Based on the quantities, and given that both acesulfame and SUC are excreted mostly unchanged in wastewater, estimates of consumption of SUC and ACE-K on the catchment area can be determined accordingly . Moreover, the comparison of breakthrough curves of both artificial sweeteners shows that ACE-K displays a higher variance with respect to SUC therefore highly impacting the extent of peak concentrations at the spring.

Code of abstract: T5.5.7
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Appalachian Valley and Ridge spring geochemistry: Monroe County West Virginia, USA

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KEY WORDS Karst, water supply, springs, geochemistry

ABSTRACT

The Valley and Ridge (V&R) physiographic province of the Appalachian Mountains plays a key role in supplying water to downstream users in the eastern USA. The region is structurally and stratigraphically complex; differential erosion has resulted in ridges defined by resistant clastic rocks and valleys underlain by soluble carbonate limestones and dolomites. The higher-elevation clastic rocks include fractured sandstones on the ridge tops and mixed-shale units found on the ridge flanks or in high-elevation valleys. Most of the hydrogeologic research in the V&R has focused on the carbonate units; however, the clastic units are essential in creating headwater streams, recharging the carbonate aquifers, sustaining base flow, and providing water supplies for private landowners and small towns. We are investigating the hydrologic and geochemical relationships between springs in the carbonate and clastic units in the V&R of Monroe County, WV. The hydrogeology in this area is further complicated by a major thrust fault that discharges warm mineral waters.

More than 250 springs have been mapped in the ~225 km^2 study area. Sixteen springs are being continuously logged for temperature; the limestone-spring waters have the most variable temperatures seasonally and through storm events; temperatures in the clastic-spring waters and thermal waters are constant in comparison. Geochemical indicators for the different spring water types have been identified to track sources of water to the surface waters in the valley. Water from the thermal springs (20-25 ^{o}C) has higher overall dissolved ions including SO4, B, Cl, Ca, and Li. Water flowing from the clastic units generally has a higher Ca/Mg molar ratio and a lower specific conductance than water from the carbonate springs. Total coliforms and *E. coli* counts are higher in the carbonate valley springs than in the clastic-sourced springs. Strontium isotopic compositions ($^{87}Sr/^{86}Sr$) of clastic and carbonate valley springs range from 0.7086 to 0.7104, and are within the range of thermal springs in the area. Ongoing work is focused on determining the relative contributions of Paleozoic carbonate dissolution, silicate mineral weathering, and thermal springs on the isotopic compositions of individual groundwater flow systems.

Code of abstract: T5.5.8
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Comparison of recent and fossilized biofilm and calcite samples from the caves of Gellért Hill, Budapest, Hungary

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KEY WORDS Buda Thermal Karst, hypogene karstification, paleoenvironment, mineral paragenesis, fossilized cave

ABSTRACT
The understanding of hypogene speleogenesis and related porosity evolution – which can lead to the creation of reservoirs with different order of magnitude – can be a key tool in exploration for hydrocarbons and ore deposits, as well as for thermal waters.
The still active Buda Thermal Karst (BTK) provides an opportunity to better understand the evolution of an active hypogene cave system into a fossilized one. So the current study has focused on the comparison of the mineral paragenesis of the already dry Aragonite Cave – located in the Gellért Hill (BTK), ~15–20 m above the recent karst water table – and the partly underwater Török Spring cave, developed right at the actual karst water level. After detailed field work and sampling from formations of the underwater and the already dry caves, macroscopic, stereo- and petrographic microscopic investigations were undertaken. A wide range of material testing instruments, including XRD, SEM+EDS, stable isotope analysis, Mössbauer spectroscopy and ICP-MS measurements were also applied on selected samples. This latter was necessary in order to identify different mineral paragenesis and their paleoenvironments. Based on the investigations, four mineral groups were distinguished, reflecting the changing paleoenvironments. One of these phases could be connected to the recently active stage of the spring cave (Török Spring, BTK).
Furthermore, the results were also compared to the findings of an in situ experiment executed in the pool of Török Spring (see Bodor et al. this volume). In the framework of this experiment the evolution of bacterial biofilms and chemical precipitates was studied throughout a whole year.
The research was supported by the NK 101356 OTKA research grant and by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2.-15-2016-00009 'ICER'.

Code of abstract: T5.5.9
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Recharge Sources and Hydrochemical Evolution of an Urban Karst Aquifer, Sete Lagoas, MG, Brazil

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KEY WORDS - Stable isotopes, hydrochemical evolution, hydrogeology, groundwater, Brazil

ABSTRACT

The current water supply for the city of Sete Lagoas, Brazil, is almost entirely groundwater from the Sete Lagoas karst aquifer, with a small contribution from a fractured igneous aquifer. Characterizing the hydrogeological processes is important for proper water resource management, avoiding contamination and other future issue. The main goal of this study is identify active hydrogeological processes, such as possible surface-ground water interactions, sources of recharge, and hydrochemical evolution of groundwater through the use of stable isotopes ^{18}O and ^{2}H and major ions data. The groundwater samples were collected in the karst aquifer, located in the central urban area, and in the fractured aquifer in the southern portion of the city. Surface water samples were collected in the seven main lakes and rainwater was sampled over one year period. The stable isotopes results indicated the groundwater origin is directly from local precipitation, having a limited recharge period. The central urban area could have surface water infiltration where the karst aquifer is in contact with unconsolidated sediments. The major ions presented the highest values at the central region, where the most karstified area from the Sete Lagoas Formation is located. These data suggest higher residence time for this water, indicating more mineralization, in concordance with the geological information.

Code of abstract: T5.5.10
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Veterinary drug occurrence in Irish karst and fractured bedrock aquifers: preliminary findings

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KEY WORDS agro-chemical, veterinary drugs, anthelmintics, groundwater, karst

ABSTRACT
Due to increased intensification of the food production system, agro-chemicals such as veterinary drugs have become a critical component in animal husbandry. Administration and application of these compounds to farm animals can potentially lead to their occurrence in groundwater. This poster presents the preliminary findings of a research project on emerging organic contaminants in Irish karst and fractured aquifers, which contributes to current groundwater research in iCRAG (Irish Centre for Research in Applied Geosciences). The project is focussed on three groups of agro-chemicals: anthelmintics, anticoccidials and pyrethroids, which are widely used as anti-parasitic drugs in Irish agriculture, and it aims to contribute to broadening the knowledge and understanding of occurrence and fate (mobility and behaviour) of both parent compounds and transformation products in the environment. The preliminary findings on the occurrence of anthelmintic residues in Irish karst and fractured bedrock aquifers are presented here.
A multi-residue Solid Phase Extraction Ultra High Performance Liquid Chromatography Tandem Mass Spectrometry (SPE-UHPLC-MS/MS) method was developed and applied in a study for the determination of 36 anthelmintic drugs in water samples from high risk sites targeted in terms of source and pathway factors. In the initial pilot study in October 2016, up to five different anthelmintic residues were detected in four of fifty-two groundwater samples (8%) and four of twenty surface waters (20%) analysed. Detections were of the order of 1-31 ng L^{-1}. The four sites with groundwater detections had zones of contribution including areas of high and extreme groundwater vulnerability, associated with shallow Quaternary deposits, and with karst conduit flow in one instance. The pilot sampling was undertaken at a time of low groundwater levels before the onset of autumn recharge. Repeat sampling of these sites together with 50 further sites is currently being undertaken (March 2017) at a time of active groundwater recharge. Preliminary results from further investigations at karst springs in one region with no detections in the pilot sampling (Co. Roscommon) have shown anthelmintic detections at several sites.

Code of abstract: T5.5.11
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.5. Karst groundwater quality and contamination

Complex pollutant transfer in fractured and karstified chalk aquifer systems in Eastern Normandy, France.

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KEY WORDS - Pollution, Pollutant transfer, karsts, aquifers systems, groundwater

ABSTRACT

Chalk aquifer systems often display dual or triple porosity textures leading to complex flowfields, not easily detected through regular groundwater level measuring campaigns which most of the time use available unevenly distributed wells opened at different depths. This often can biased groundwater flow interpretation and lead to partially erroneous flowfields or piezometric maps. This is a real problem when dealing with pollution migration, as finding pollution sources, predicting plume evolution or pollutant concentration trends and setting up corrective measures to protect water resources.

This paper intends to discuss complex pollution transfer in two chalk aquifer valleys in eastern Normandy where pollutants do not seem to only follow flowlines shown on available groundwater level maps; indeed, divergent pollutant transfer also take place along fractured axes and karst developments which can often be associated to geological discontinuities, as was already highlighted through model calibration processes in the Avre river catchment.

In the Commerce valley case, a rare emerging pollutant, N-nitrosomopholine, was discovered to migrate in two opposite directions from a single source point identified in the upper Valley: indeed, this pollutant was both found south and downstream in the fractured and porous aquifer, and way up north in a karst channel system used for drinking water purposes, in what was thought to be a completely different watershed.

In the Iton valley case, the pollutants are volatile organohalogenated compounds (VOH) which are widespread in Normandy and often stem from historical industrial pollutions. Several potential VOH sources were identified in industrial areas in the valley south from contaminated drinking water wells; yet the groundwater flow map suggest an eastern origin for the pollution source...

This situation often encountered in the chalk aquifer systems of eastern Normandy makes it difficult to establish “cause to effect” links between pollution sources and contaminated drinking water wells. To tackle this problem and clarify flowline interpretation, a multi-parameter approach based on geological and hydrogeological criteria has been developed; it is discussed in this paper.

Code of abstract: T5.6.1
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

Classification of Free Phase Gas in Springs

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KEY WORDS - Bubbles, Categorization, Karst, Facies, Nitrogen

ABSTRACT

The mechanisms leading to the formation of bubbles in springs have received minimal attention beyond commercial interest in soda water. The presence of free-phase gas or vapor bubbles at a spring may provide valuable information about flow paths and mechanisms associated with the discharge site. Additionally, free-phase gas or vapor bubbles may strip dissolved gasses from solution and introduce error into the assessment of spring composition.

Similar to Meinzer's (1927) classification of springs by discharge rate, this presentation provides a method for discussing bubble phenomenon in springs to organize literature and foster future research. A classification system of seven types of phenomena describing spring bubbles is proposed. Gas bubbles found at a spring rarely occur as a single gas, therefore these mechanisms may overlap, however the proposed structure for classifying gas discharge facies provides a fundamental framework.

Karst aquifers provide favorable conditions for the development of bubbles (particularly Entrained Air (II) and Degassed Nitrogen (III) bubbles). Some rhythmic springs appear with intermittent air bubbles as described by Gavrilović (1967) in the Dinaric Karst Region. Degassed, or pressure-drop, bubbles arise from the phenomenon of a drop in partial pressure induced by an increase in fluid velocity (velocity pressure or kinetic hydraulic head) following Bernoulli's principle. As the velocity pressure drops, the partial pressure of a dissolved gas can exceed the pressure of the environment and ebullate.

The seven bubble facies convention and clarification of terms provides a framework to establish a vernacular and facilitate the exploration of this often-overlooked phenomenon in springs. The approach is intended to foster defined lines of investigation and facilitate the exchange of knowledge and advancement of the field. By exploring the free gas phase discharges in springs, researchers will gain additional insight into the inner workings of aquifers.

Code of abstract: T5.6.2
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

Fluorescence-based multi-parameter approach to examine the water quality of alpine karst springs

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KEY WORDS - karst groundwater, water quality, organic material, excitation-emission matrix (EEM), particle-size distribution

ABSTRACT
Especially in alpine regions, karst springs are an important source of drinking water but also highly vulnerable to temporary contamination, particularly after rainfall events. This variability of water quality requires rapid determination methods of contamination parameters. We present a fluorescence-based multi-parameter approach to determine the dynamics of organic carbon, fecal bacteria and particles at alpine karst springs.
Excitation-emission matrices (EEMs) were used to identify fluorescent dissolved organic material (FDOM). Spearman's rank correlation analysis revealed a high relation between total organic carbon (TOC) and peak A and peak C fluorescence, indicating that a large part of the organic material in the spring waters is related to humic-like substances. A significant correlation was also obtained by comparing protein-like fluorescence (peak T) with conventional bacterial determination methods, indicating that protein-like fluorescence is directly related to bacterial contamination. However, at low bacterial contamination levels, the observed correlation with fluorescence peak T was much lower. At one spring, particle-size distribution and turbidity were additionally measured. We observed a strong correlation between small particle fractions (1.0 and 2.0 µm), a secondary turbidity peak and coliform bacteria in response to rain events.
Our results demonstrated that all investigated karst springs showed fast and marked responses of all investigated water quality parameters to rain events. At one spring, which acts as base outlet of a karst aquifer, we observed a constant discharge while all other parameters responded to the rain event. This fact shows that a constant discharge does not necessarily mean constant water quality. At high contamination levels, protein-like fluorescence analysis is a suitable method for a rapid assessment of bacterial contamination. A combination of fluorescence measurements and particle-size analysis is therefore a promising approach for a fast identification of organic contamination especially in regard to the time consuming conventional bacterial determination methods. A combined measurement of these parameters can also act as an early-warning system for organic contamination originating from the land surface.

Code of abstract: T5.6.3
Type of presentation: Oral presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

Karst spring catchment delineation using correlation between of hydrographs and satellite global precipitation measurements

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KEY WORDS spring, hydrograph, GPM, catchment, delineation

ABSTRACT
Delineation of karst spring catchments is critical for global water resource protection. This typically entails three-dimensional geological mapping; spring hydrograph monitoring with water balance calculations; hydrochemical and isotopic analyses; and confirmation by artificial tracer tests. In an attempt to speed and support this formidable process, we have developed a method for rapid, reconnaissance-level springshed delineation using correlation of hydrograph data with high-resolution satellite-based global precipitation data. In a synthetic test, using eight months of tipping rain gage data as a proxy hydrograph, the method correctly located the gage; representing 1 satellite pixel out of the global total of 4.32 million. Blind tests on hydrographs from Missouri, Texas, Switzerland and Austria also correctly located the published catchments of their corresponding springs. The method was applied to a mysterious spring in Pennsylvania with discharge seven times greater than the estimated recharge in its topographic catchment. This spring shows apparent "piston effect" discharge pulses with no associated change in temperature, conductivity, or other physico-chemical parameters. The correlation between the hydrograph and satellite precipitation data identifies several adjoining pixels, roughly 60 km away, where precipitation events are repeatedly followed, in under an hour, by discharge pulses in the spring. This suggests transmission of pressure pulses along a highly permeable (highly fractured and/or karstified) pathway that crosses multiple physiographic provinces and tectonic boundaries. This unexpected hydraulic connection requires further study and dye trace confirmation. Since the correlation method successfully located several known spring catchments and the rain gage location in blind testing, identification of the unexpected recharge zone for the Pennsylvania spring immediately suggests where to search for dye injection points, and this highlights the potential utility of this method for global water resource protection and groundwater studies.

Code of abstract: T5.6.4
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

High Resolution Site Characterization in Karst Systems: Integrated 3D Geophysical Analysis

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KEY WORDS – Electrical Resistivity, LNAPL, Remediation, Biodegradation, Biogeochemistry

ABSTRACT
Environmentally impacted karst systems are considered difficult sites to manage due to highly heterogeneous geology and groundwater velocities which are faster than predicted (based on continuum hydrogeology). Karst sites would be much easier to manage if the locations of impacts were known; the contamination tends to stay in high hydraulic conductivity zones and does not often penetrate far into the rock matrix.

An electrical subsurface imaging technique designed specifically to detect contaminants (developed at Oklahoma State University and commercially applied as Aestus GeoTrax Survey™), has been successfully applied at multiple impacted karst sites. The method provides accurate conceptual site models (CSMs) to focus remediation efforts. The primary lessons learned were 1) the locations of key drilling/sampling sites were not detected by historical drilling data obtained without the benefit of targeting from subsurface imaging work, and 2) the electrical structure of karst systems make them good candidates for electrical high resolution site characterization. Examples of source zones and sinkhole characterization will be used to illustrate the approach.

Code of abstract: T5.6.5
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

Geologic, Hydrogeologic and Geophysical Analysis for Groundwater Exploration in Karst Formation

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KEY WORDS - groundwater, audio magneto-telluric, geophysical, resistivity, MODFLOW

ABSTRACT

Increased use of geophysical methods along with groundwater exploration and subsurface assessment techniques over the last decade has resulted in cost-effective site investigation methods. In this study, the audio magneto-telluric (AMT) method was used to determine soil formations and the presence of groundwater. A total of ten AMT soundings were carried out on a stretch of approximately 250 meters in the city of Knaisseh, Shouf, Lebanon (33°42′53.38″N 35°34′27.22″E), using Stratagem EH4. The geophysical survey was conducted to detect layers with dissimilar lithostratigraphic properties and corresponding depths. Results were compatible with the geological cross-section, delineating three layers with different resistivity zones: C2a (Mdairej Formation), C1 (Shouf Sandstone), and J6 (Bikfaya – Karst Formation). Water-bearing strata were evaluated with C1 and J6 being characterized as potential aquifers in the aforementioned site. A well tapping the Karst aquifer under steady state pumping was also modeled using USGS MODFLOW. Inputted hydraulic properties were obtained by correlating attained geo-electric data with previously published transmissivity – resistivity relationships, of aquifers with similar geological formations. Spatial and temporal drawdown variations of the well were calculated and analyzed.

Code of abstract: T5.6.6
Type of presentation: Poster presentation
Topic: T5. Groundwater in Karst Systems
Session: T5.6. Novel methods and techniques for karst aquifer characterization

Radon as a natural tracer of underwater hypogenic caves

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RADON, HYPOGENIC, UNDERWATER CAVE, MIXING, TRACER

ABSTRACT
Using radon222 as a natural tracer is a novel approach in the underwater cave exploration and the active hypogenic cave research. The research area, the Molnár János cave is one of the largest caves of an unique karst system, the Buda Thermal Karst (Budapest, Hungary). The cave system mainly characterized by water-filled passages. The cave is located at one of the main discharge areas of the Buda Thermal Karst and the major outflow point of the waters of the cave system is the Boltív spring, which feeds the artificial Malom Lake. Previous complex hydrogeological studies and radon measurements in the cave system and in the spring established the highest radon concentration (in average 44 Bq/L) in the springwater. The origin of radon was identified in the form of iron-hydroxide containing biofilms, formed by mixing of waters, which efficiently adsorb radium from the thermal water component and cause local radon anomalies. Since mixing of waters is responsible for the formation of the cave as well, these iron-hydroxide containing biofilms and consequently high radon concentrations mark the active cave forming zones. The aim of the study was to use the radon as a natural tracer to locate active mixing and cave forming zones. Based on previous radon measurements it is supposed that the active mixing and cave forming zone has to be close to the spring, since the highest radon concentration was measured there. Therefore, the radon activity concentration mapping was carried out with the help of divers and involving that part of the cave which closest to the spring. Based on our measurements the highest radon concentration (84 Bq/L) ever was achieved in the springwater. Based on the radon concentration distribution direct connection and active karst conduit was established between the spring and the deepest room of the researched part of the cave, which was verified by artificial tracer as well. However, the distribution of radon in the cave passages shows lower concentrations (18-46 Bq/L) compared to the spring, therefore an addition deep inflow from a hitherto unknown cave passages is assumed, from which waters with high radon content arrive to the spring. These passages are supposed to be in the active cave formation (mixing) zone. The Buda Thermal Karst research was funded by the Hungarian Scientific Research Fund under the grant agreement no. NK 101356.

Code of abstract: T6.1.1
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Heterogeneous hydraulic properties of an insular aquifer clarified by a tidal response method with simple decomposition techniques

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KEY WORDS groundwater observation time series, nonrecursive digital filtering, discrete Fourier transform, Jacob-Ferris tidal method, hydraulic diffusivity

ABSTRACT
Two simple frequency-decomposition techniques were used as part of a tidal response method to derive hydraulic diffusivities of a freshwater-lens aquifer. Digital high-pass filtering can separate tidal components of diurnal and shorter periods from longer-period components. Discrete Fourier transform can be used to isolate a specified tidal component. These techniques are easy to practice using built-in functions of spreadsheet software. The used techniques were each optimized for frequencies of known major tidal components. The isolation of specified tidal signals helps reduce errors of a basic tidal response method that uses in the calculations amplitude attenuation and phase lag of a simple sinusoidal wave of groundwater fluctuations. Another advantage of the present tidal method is employing two groundwater time series collected from near-shore and relatively inland sites affected by the same ocean tide. The method uses no surface-water observation and this avoids errors derived from generally possible surface-water/groundwater boundary effects.
The tidal response method with simple decomposition techniques were used to investigate aquifer properties of an uplifted limestone island, located in a subtropical region of Japan. A freshwater lens is the principal water resource for that island and its sustainable development has been desired. Significant hydraulic layering has not been reported in the limestone aquifer. Pairs of groundwater-level time-series data collected by simultaneous observations at near-shore and inland sites were subjected to the tidal response method. Estimated hydraulic diffusivities were of the same order of magnitude as those calculated using previously reported hydraulic conductivities determined by a pumping test. The results demonstrated heterogeneous aquifer diffusivity in the island, typically with larger values in the southeastern coastal part than in the northwestern coastal part, which is consistent with the planar distribution of the entire freshwater lens and the position of its maximum thickness a little biased toward the northwestern side.

Code of abstract: T6.1.2
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Optimising the management of the Gozo Mean Sea Level Aquifer (Malta)

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KEY WORDS Groundwater, Island, Quantitative Status, Model

ABSTRACT
The island of Gozo with a land-area of 68.67 square kilometers is the second largest island in the Maltese archipelago. The water demand generated by the population, their economic activities and the needs of the water dependent environment is estimated to exceed the available natural freshwater resource-base. In as much the island is directly linked to a sea-water desalination plant in the island of Malta to supplement potable water needs. The agricultural sector on the island is totally dependent on groundwater and harvested rainwater, although the commissioning of a treated wastewater polishing plant later in 2017 will introduce an alternative water resource, reducing the impact on groundwater.

Malta's 2nd River Basin Management Plan (RBMP) estimates that the mean sea level aquifer in Gozo still suffers from overexploitation, and hence is classified as being in poor quantitative status. The aquifer system is utilized for the abstraction of water intended for human consumption and the agricultural and commercial sectors. The strategic importance of groundwater for the islands therefore calls for the development of tools for its protection, in order to protect it from over-abstraction and related risks of sea-water intrusion.

This issue was addressed under the FREEWAT project (Rossetto et al., 2015) through the development of a management tool (numerical model) of the Gozo mean sea-level aquifer which permits the evaluation of the quantitative status of the water body. The model permits the assessment of the impact of measures programmed under Malta's 2nd RBMP and their capacity to achieve good quantitative status. Furthermore, the model introduces a spatial dimension in the water balance assessment by taking due consideration of the spatial variation of groundwater abstraction, and therefore helps the identification of regional water management issues. The model thus supports the optimized management of this aquifer system through increasing the reliability of quantitative status assessments.

The model also permits the assessment of future groundwater management scenarios, including the effects on quantitative status arising from climate change impacts, such as reduced precipitation and increased abstraction, and therefore is also an effective tool to support water managers in the identification of the necessary adaptation measures.

Acknowledgements
This paper is presented within the framework of the project FREEWAT, which has received funding from the European Union's HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.

References
Rossetto, R., Borsi, I. & Foglia, L. FREEWAT: FREE and open source software tools for WATer resource management, Rendiconti Online Società Geologica Italiana, 2015, 35, 252-255.

Code of abstract: T6.1.3
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Assessment of multi-level groundwater flow dynamics in the context of Irish karst hydrogeology

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KEYWORDS Ireland, karst, submarine groundwater discharge, groundwater modelling, tracer studies

ABSTRACT
The understanding of groundwater (GW) flow dynamics in the relatively shallow karst aquifers of the Republic of Ireland is important due to their extensive outcrop, their influence on seasonal GW flooding and terrestrial ecosystems within *turloughs*, as well as freshwater discharge along the coast.
This study investigates the flow dynamics and discharge patterns of the catchment of Bell Harbour located in the north-east of the karst Burren plateau. The catchment drains into the Atlantic Ocean in western Ireland and it rises up to >300 masl inland. Previous studies concluded that the aquifer drains entirely into Bell Harbour bay via submarine and intertidal springs.
To better understand the GW flow dynamics, this study has deployed a hydrometric monitoring network to measure continuously climate, EC and temperature fluctuations within the outlet of the bay and at the outlet of an intertidal spring for > 1 year. Furthermore, an open borehole has been continuously equipped with a set of CTD divers. Single borehole tracer studies were conducted to investigate inflow and outflow zones within the borehole and to quantify vertical GW flow velocities and tracer breakthrough within the borehole.
The results suggest that the intertidal spring acts as an overflow spring even during periods of continuous rainfall, draining periodically freshwater to the bay. Accordingly, the concentration of EC within the bay is not a direct function of rainfall but rather of the functioning of the overflow spring and aquifer storages.
Open borehole hydrographs show a rapid response to rainfall followed by an extremely steep recession indicating multiple inflow and outflow zones.
This study concludes that the catchment of Bell Harbour is drained by a two-level conduit system: a) a shallow network being periodically activated and draining into the bay, and b) an extensive deep conduit system that is permanently saturated draining the catchment offshore via submarine springs. The deep network and latter springs must have formed during periods of lower sea level elevations, perhaps during the Pleistocene.
Finally, a two-level discrete conduit network conceptual model has now been proposed for the flow dynamics within the catchment, demonstrating the hydraulic functioning of the two-level karst system, which never has been hypothesised before.

Code of abstract: T6.1.4
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Groundwater research on a Dinaric karst island – the island of Vis case study (Croatia)

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KEY WORDS karst aquifer, salt/fresh water relations, sanitary protection zones, tracing experiment

ABSTRACT
Adriatic karst island of Vis has a public water supply from its own groundwater for decades. First organized water supply is connected with costal spring Pizdica in Komiža bay, where extraction site was dug in a rock in 1950s with the purpose of army water supply in case of nuclear war. The water was also used for Komiža settlement. In late 1960s and 1970s the Korita pumping site was established after a bulk geological, hydrogeological and geophysical research. There are six boreholes (wells) with depths from 145 to 200 m. During establishment, minimal pumping quantities were around 3 L/s on Pizdica and some 27 L/s in Korita. In 1999 new phase of research was performed, and conceptual model of island's aquifer has been presented. Structural geological, hydrogeological and hydrochemical researches provided the basis of that model and starting point for future sanitary protection of the aquifer. After reinterpretation of former pumping tests it was decided that extraction rates in Korita could be increased up to 40 L/s without quality deterioration. In 2012 the research continued with a tracing experiment, conceptual model was modified and sanitary protection zones delineated. Even though this is a Dinaric karst island, good positioning of Korita pumping site combined with some favorable geological features resulted in long term sustainable public water supply of the whole island. Nevertheless, the water demand will probably increase in the coming years and some additional quantities should be put in use. Considering that, part of the last research phase was targeted on a few locations where more groundwater could be extracted in the future. The main methods used were hydrogeological and geological mapping, as well as the geophysical research (geoelectrical sounding was performed because of the studied depths – over 300 m). Tracing experiment resulted in groundwater velocities determination in complete accordance with previously defined hydraulic conductivity of the rock mass in Korita area. Apparent velocities in main flow direction were approximately 0.27 cm/s and perpendicular to that direction below 0.1 cm/s. Hydraulic conductivity of rock mass in that part of the island is within the order of magnitude of 10^{-5} m/s. Position of groundwater divide between Korita and Pizdica (sub)catchments was also determined. Four researched micro-locations had different perspective for further hydrogeological research, and one is chosen as possible early warning system monitoring site.

Code of abstract: T6.1.5
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Exploration and Hydrogeological Assessment of a Deep Coastal Aquifer System in Tanzania

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KEY WORDS - Coastal aquifers, Hydrocarbon exploration, groundwater modeling, aquifer development plan

ABSTRACT

Dar es Salaam (DSM) is the largest city and economic engine of Tanzania. Recent years have brought significant and unsustainable growth to the City, and both planners and utilities are struggling to cope with the pressures that accompany urban growth, including an asymptotic water demand curve.

Funded by the Government of Norway, a major groundwater exploration and assessment project has been undertaken to test and/or verify a conceptual hydrogeological model which places a regional coastal aquifer system at the doorstep of the City. Results of the assessment have not only verified the concept, but the new resource is estimated to have a sustainable supply potential of more than 200,000 m^3/d.

Implementation of the Kimbiji Aquifer project has been a pioneering endeavor. It has bridged the oil and water sectors, whereby onshore and offshore hydrocarbon exploration data were used to interpret the architecture and geometry of the aquifer system. Without these data, it would not have been possible to place boundaries on the system or estimate its total thickness. Nothing similar has been attempted in Tanzania before and initial skepticism about the new resource has since been replaced by expectation.

The hydrogeological assessment work included the drilling, geophysical logging and testing of 600 m deep exploration boreholes, numerical groundwater modeling and water quality characterisation. Specific outputs were an Aquifer Development Plan and a Strategic Environmental Assessment of the proposed plan. Results will assist regional and national authorities to make informed planning decisions, and to both scope and cost infrastructure requirements over a 30+-year planning horizon.

Code of abstract: T6.1.6
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Characterization and numerical model of Nauru Island (Pacific Ocean) for groundwater management in different sea level scenarios

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KEY WORDS saltwater intrusion, island characterization, numerical transport model, climate changes effects, sea level rising

ABSTRACT

Groundwater occurs on small islands as either perched (high level) or basal (low level) aquifers and usually represents the main high quality and naturally occurring freshwater. On many small coral and limestone islands, the basal aquifer takes the shape of a 'freshwater lens' which underlies the whole island. These lenses accumulate from rainfall percolating through the soil and reside in fragile hydrodynamic equilibrium with the underlying seawater, separated by slight differences in density. The very limited nature of water resources, worsened by climate changes, and the vulnerability of these islands makes water resources sustainable management in these zones a very high priority. The Republic of Nauru (22 km^2) is an isolated, uplifted limestone island located 41 km south of the equator. Nauru is one of the places in the world that have no better solution of their water supply than to use groundwater given that desalinization is really expensive and rainfall not enough for fulfilling the population needs. During a two years project, hydrogeological data have been collected in Nauru for the island characterization, performing different activities such as groundwater level surveys (taking into account the tidal fluctuation effects), electrical conductivity monitoring, pumping tests, Global Navigation Satellite System topographic survey and geoelectrical investigation of the subsoil. The island characterization and the developed conceptual site model has been the starting point for the implementation of the density-dependent numerical transport model used to evaluate the effect of private wells extraction on saltwater intrusion and salt distribution in groundwater. In fact different wells are located along the coastline, especially in the northern part of the island. The numerical model has then been used for evaluating the possibility to manage the extraction from the present pumping wells in order to maximize the groundwater availability and minimize the saltwater intrusion. The effect of sea level rising driven by climate changes on fresh groundwater distribution below the Island has been also assessed using the implemented numerical model, and the extraction management has been evaluated in different sea level scenarios.

Code of abstract: T6.1.7
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Climatic induced salinization in the Porto Santo island (Portugal)

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KEY WORDS - hydrogeochemistry, coastal aquifers, islands, salinity, fluorosis

ABSTRACT
Detailed hydrogeochemical investigations have been carried out in the Porto Santo volcanic island (Portugal) to characterize groundwater quality and study origin of groundwater salinity in order to develop management measures to optimize groundwater use for irrigation. The geochemical results obtained point to different sources of groundwater salinization: a primary salinization that may be mainly attributed to climatic drivers due to semi-arid climatic conditions that potentiate evaporation; another source of salinity due to water-rock interaction in aquifer formations which have high natural background salinities (geogenic origin); and, one last source of salinity that may be related to modern seawater intrusion due to over pumping along the coast for irrigation of touristic green areas. High TDS of the groundwater has rendered the water unsuitable for direct use and fluoride concentration range of 1.5 to 5 mg/L objects its application for drinking purpose and raises concern of dental and skeleton fluorosis. High Sodium Adsorption Ratio (SAR), salinity and boron concentration limits the crop type selection for agricultural practices on the island and requires specific measures for the groundwater to be used for crop irrigation.

Code of abstract: T6.1.8
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Evolution of saltwater intrusions in the low-lying coastal areas in Southern Denmark

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KEY WORDS Saltwater intrusion evolution, low-lying coast, heterogeneous geology, numerical modelling, SEAWAT

ABSTRACT

The freshwater supply in coastal areas worldwide is often dependent on groundwater resources. In coastal regions where the topography is low, abstraction rates high and the land managed (e.g. drained) aquifers are particularly vulnerable to saltwater intrusions. In the border region between Denmark and Germany where large areas were reclaimed from the Wadden Sea during the last centuries, airborne electromagnetic (AEM) surveys show salt water intrusions up to 20km inland. For the last 200 years these low-lying areas have been protected from flooding by dikes and have been heavily drained in order to keep the land arable.

This study presents a 3-dimensional density driven groundwater flow and transport model covering an area of 1700km^2, adjacent to the Wadden Sea, which is used to investigate the evolution of saltwater intrusions. The heterogeneous geology spans from Miocene through Quaternary deposits and is described in a detailed voxel model that serves as a base for the flow and transport simulations with MODFLOW and SEAWAT. The salt water intrusion is simulated for the last ten thousand years and changing conditions caused by flooding and dike construction are taken into account. The extent of the simulated saltwater intrusion is compared to the location of the freshwater/saltwater interface delineated based on AEM and borehole data.

The study identifies two main features controlling the progression of seawater into the coastal aquifers. In the deeper aquifer system geological features such as buried valleys provide preferential flow path for the intruding saltwater. Land management and dike construction transformed the shallower aquifer system from being salt saturated while the area was flooded to being refreshed after the dike was built.

Code of abstract: T6.1.9
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.1. Modelling of coastal and island aquifers

Large-scale modeling of saltwater intrusion in North-Western Germany – submitting abstract to

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KEY WORDS coastal aquifers, saltwater intrusion, large-scale numerical modeling, development of the coastline, Germany

ABSTRACT
Groundwater salinization of coastal aquifers is a problem that may intensify due to climate change and sea level rise. Also, saltwater intrusion and upconing can occur due to unsustainable groundwater extraction. The area under investigation is located in North-Western Germany between the rivers Ems and Weser at the German Bight of the North Sea. Parts of this area (salt marsh) have been made available for human use by installing dikes and drainage measures throughout history. Most likely, these anthropogenic factors have a major influence on the present extent of saltwater intrusion. To quantify which factors have the largest influence on groundwater salinization, a large-scale numerical model is currently built. In the first step, the model aims at replicating the present head distribution and the location of the freshwater-saltwater interface by incorporating historical morphological states of the area and the installation of dikes and drainage measures. Later, the model will be used for future scenarios in order to assess the potential impact of, for example, sea level rise.

Code of abstract: T6.2.1
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Novljanska Žrnovnica spring – Specifics of groundwater discharge and abstraction regime

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KEY WORDS - Coastal karst spring, periodic salinization, different recharge areas, intake structures

ABSTRACT

Novljanska Žrnovnica is a complex, coastal karst spring on the eastern coast of the Northern Adriatic draining groundwater from large and mutually distant areas – Lika and Gorski Kotar. The first spring water intake had been established in 1932. With growing water demand, new intake structures were gradually built. The "Old" spring water intake located in the central part of the spring zone, most susceptible to salinization was followed, by the "New" spring water intake where water periodically becomes saline, and by the "Čardak" intake structure in the eastern part of the spring zone which never becomes saline. The total spring intake capacity is 0.4 m^3s^{-1}, but in certain years increased chloride content occurs at abstraction quantities half that amount. The mean annual spring yield is app. 2.0 m^3s^{-1}, maximum discharges exceed 5.0 m^3s^{-1}, and maximum abstracted quantities reach 0.3 m^3s^{-1}.
What makes the spring specific is the fact that certain spring branches, although closely located (the spring zone is app. 100 m wide), react differently to rainfall in different parts of the basin. Likewise, risks to saltwater intrusion in different parts of the spring zone are very different. For example, in late summer 2003, a sudden increase in electric conductivity from app. 200 μScm^{-1} up to 3660 μScm^{-1} was recorded over a span of only a few days in the waters of the central spring zone (Old and New structures). At the same time, at identical abstraction quantities of app. 0.1 m^3s^{-1} in both spring zones there was no increase in electric conductivity recorded in the eastern part of the spring zone (Čardak spring). Such reaction of water in individual intake structures, together with the results of geophysical investigations, have directed the spring development concept towards a drilling new wells in the eastern part of the spring zone, locally isolated due to its geological composition from direct seawater intrusions into that part of the aquifer.
In recent years, the capacities of a new well at the hinterland of the Čardak intake structure and of temporary spring Mlinice have been investigated. Abstraction tests conducted in the dry period indicate a well intake structure with a very high yield where additional 0.15 m^3s^{-1} can be abstracted without the chloride content increasing.

Code of abstract: T6.2.2
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Groundwater characterization in the semi-arid Punata alluvial fan (Bolivia)

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KEY WORDS Hydrochemistry; Stable isotopes; Geophysics; Alluvial fan

ABSTRACT

To plan a sustainable management of groundwater resources is necessary to understand the aquifer system geometry and some hydrogeological process. Alluvial fans are generally located in arid and semi-arid regions, and they use to have permeable layers where groundwater is stored. In the Punata alluvial fan the monitoring of groundwater level shows a decreasing trend of the water table, and probably the main reason for this decline is due to the fact that groundwater extraction has equaled or exceeded the natural recharge during the last few years. In this region the main socio-economic activity is the extensive agriculture, thus a shortage in groundwater supply might lead to conflicts between local water supply companies serving urbanized areas and agricultural interests. In order to plan a sustainable management of groundwater, the aim of this study is to use hydrochemical and geophysical methods for providing information and propose a hydrogeological model in terms of groundwater recharge, flow patterns, chemical evolution, and aquifer system geometry. A specific objective of this project is to train Bolivian and Scandinavian students on PhD, MSc and BSc level. A further objective is to transfer knowledge of integrated geophysical aquifer mapping to local authorities within the groundwater and environmental sector.

Electrical Resistivity Tomography (ERT), Induced Polarization (IP), and Time Domain Electromagnetics (TDEM) were the geophysical methods used for refining the geological conceptual model of the aquifer system. A total of 30 Km of ERT and IP were collected, and 130 TDEM soundings were performed. The results show a complex structure in the apex region of the fan dominated by fluvial and colluvium deposits, while in the distal area the stratification is smoother and is dominated by lacustrine deposits. ERT surveys showed that the top layers are composed of coarse material, and the confining bottom layer is mainly composed of clay and silt. IP was useful during the ERT interpretation for solving ambiguities. TDEM provided hints about the existence of a very thin brackish layer located just below of the coarse material.

The used hydrochemical analysis were: 1) major ion chemistry and chemical weathering process, 2) Stable isotopes (deuterium and oxygem-18), and 3) statistical analysis (Hierarchical Cluster Analysis and Principal Component Analysis). A total of 45 water samples were taken, and come from groundwater and surface water. The samples from groundwater are located within the Punata alluvial fan, while the latter are distributed along water bodies in the neighboring basins. The samples were spatially distributed in order to take into consideration all the possible recharge sources. The analysis of $\delta^{18}O$ and $\delta^{2}H$ concentrations in water samples assisted in identifying that groundwater in the Punata alluvial fan is mainly recharged by heavy flash floods, rather than precipitation or rivers base flow. The multivariate statistical and hydrochemical analysis indicated that weathering of carbonated rocks contributed to the increase of Ca^{2+} concentration, and that there is an increase of Cl^{-} and TDS concentration in the middle and distal part of the fan. These changes in the ion concentrations leads to established that groundwater flow is from the East to the West and Northwest of the fan.

The results obtained from the geophysical surveys provide valuable information for building a geological conceptual model of the aquifer system in the Punata alluvial fan. While the hydrochemical results have implications for the knowledge of hydrogeological processes in alluvial fans in general in that it shows that the integration of hydrochemistry, stable isotopes and multivariate statistical can be useful tools for characterizing flow patterns, recharge mechanisms and groundwater mineralization processes. The integration of the results might contribute in the making of policies for sustainable groundwater management in the Punata alluvial fan.

Code of abstract: T6.2.3
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

The state of art on the coastal aquifers database coming from the CAD-CZM network of IAH

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KEY WORDS Coastal aquifers, seawater intrusion, webgis

ABSTRACT

In the last two years, in the framework of the IAH network on Coastal Aquifers Dynamics and Coastal Zone Management, it has been carried on a systematic collection of data, referred to coastal aquifers characterization, as from the geological and hydrogeological point of view, as from the geochemical one, including also the tools for their characterization, and the kinds of their exploitation. Information, referring each coastal aquifer, comes out from papers or proceedings of congresses, and they have been put inside a questionnaire, which has been sent to each of the authors of collected paper or proceedings, to be checked and corrected by them. Only after this procedure, all collected data are organized and have been uploaded in a webgis, set up at the internet address www.iah-cad-czm.net, where for any coastal aquifer, whose data have been collected, and checked by the original author, it has been uploaded a filled questionnaire, edited in pdf. The target of the website, and of the information, uploaded, on it, is to share them among researchers and stakeholders, interested in coastal aquifers knowledge and management, as the same website presents some updated information on people living in coastal areas, all over the world, just to highlight the increasing pressure on coastal aquifers, due to water demand growing up. Until now, they have been uploaded more than 50 filled forms, referred to the all continents in the world. About half of them are referred to Europe, as they are 26, but there are also 11 coming from Africa, 8 from Asia, 8 from America, and 2 from Australia. In this meeting I'm interested in presenting first results of analytical and statistical elaborations, referred to pieces of information collected in the website. It means that they will be reported results coming from the analysis of different kinds of information, they have been collected, such as if and how many coastal aquifers, present in the database, are porous, fractured or karst, or which are the most spread kinds of exploitation and which are the more frequent used tools for investigations. By this way, it will be possible to have a first overview on the knowledge we have, until now, on these coastal aquifers.

Code of abstract: T6.2.4
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Tidal-driven dynamics and evolution of a young freshwater lens on a juvenile barrier island, 'Ostplate', Spiekeroog

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KEY WORDS coastal aquifer, water levels, groundwater salinity, groundwater ages

ABSTRACT
Freshwater lenses are highly relevant for coastal ecosystems and drinking water supply on barrier islands. The freshwater lens below the very young eastern part of the North-Sea barrier island Spiekeroog ('Ostplate') presented in this study is currently developing (since the 1970s). Due to the absence of coastal protection measures, the formation of this freshwater lens is occurring unaffected by anthropogenic influences and is, therefore, exposed to dynamic changes, e.g. storm tides and geomorphological changes. A preliminary numerical model indicated that it will take centuries before the freshwater lens reaches a state of equilibrium and its final size (Röper et al., 2013). So far, vertical thickness, tidal and seasonal dynamics as well as the temporal evolution were unknown.
Five shallow and three multi-level wells were installed along a transect from north to south through beach, dune and salt marsh areas to locate the vertical extent of the freshwater lens and to record water levels and groundwater salinities over a period of one year in order to assess tidal- and seasonal-driven dynamics. By means of direct-push, depth-specific groundwater samples were extracted additionally to determine the distribution of groundwater residence times in order to infer on flow patterns.
Results show that the freshwater lens presently has a vertical thickness of 4-5 m. The transition zone between fresh- and saltwater is not a sharp boundary, but a diffuse zone of several meters thickness. Water levels display a delayed tidal signal of decreasing amplitude with increasing distance to shoreline and an influence of recharge due to precipitation. Groundwater ages within the freshwater lens are expected to increase with increasing depth towards the transition zone. Wells at the dune base were exposed to winter storm tides, which salinized the uppermost well following inundation.

Literature:

Röper, T., Greskowiak, J., Freund, H., Massmann, G. (2013): Freshwater lens formation below juvenile dunes on a barrier island (Spiekeroog, Northwest Germany). Estuarin, Coastal und Shelf Science 121-122, 40-50

Code of abstract: T6.2.5
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Direct measurements of submarine seepage of groundwater into the Puck Bay, Poland

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KEY WORDS coastal hydrogeology, Puck Bay, filtrometer, gradientmeter

ABSTRACT
Many long-term studies in Institute of Oceanography University of Gdansk (Jankowska-Piekarek 1994) were carried out to investigate groundwater discharge into the bottom of the Puck Bay in the southern Baltic Sea. These studies usually focused on the changes in water chemistry and salinity. In many cases, data from submarine and coastal drillings were also analyzed. In the August 2015 thermal imaging was applied to seek regions of groundwater seepage into the bay. Aerial photographs made in summer using a thermographic camera feature dark blue spots, which represent regions with cooler waters (<15°C), and yellow, orange or red spots, which represent regions with waters that are warmer (>18°C). Areas where intensive seepage of water into the Puck Bay takes place are cooler relative to adjacent areas.
The results of thermal imaging were verified by in situ measurements of the direction and intensity of water flow in the bottom sediments of the bay. These measurements required designing and constructing two new devices - the gradientmeter, which measures the direction of water flow, and the filtrometer, which allows to determine the intensity of this flow. Both devices are briefly presented in this paper. Moreover, in areas where such measurements were performed, water was sampled at two depths: near the bottom of the bay and at the surface. The low salinity of deeper water confirmed the presence of submarine groundwater seepage into the Puck Bay.
Maps of hydraulic gradient variability, groundwater seepage intensity and the spatial distribution of hydraulic conductivity of bottom sediments were developed. The research revealed a high correlation between the results of thermal imaging interpretation and the results of in situ measurements of submarine groundwater seepage. It can be hypothesized that thermal imaging can accurately characterize such seepage once the seepage intensity is properly calibrated based on the measurements of the hydraulic gradient and the intensity of water flow in bottom sediments.

Acknowledgements
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1. UMO-2011/01/N/ST10/02012 entitled :" Identification if filtration parameters of bottom sediments in area od surface water and groundwater interaction".
2. NCN 2015/17/8/ST10/01833 entitled: "Conditions of the daily fluctuations in the levels of water in rivers and springs taking into account the influence of hyporheic zone".

Code of abstract: T6.2.6
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Recirculation rates within beach sediments under meso-tidal conditions (Spiekeroog, Northern Germany)

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KEY WORDS - submarine groundwater discharge- saline fresh water interaction - beach topography change

ABSTRACT

Submarine groundwater discharge (SGD) was identified as an important source for nutrients and trace metals from land into the sea. In coastal aquifers, SGD includes a terrestrial freshwater component as well as saline proportion originating from tidally driven recirculation of seawater. Several studies on numerical modelling of fresh and saline water interactions below island bodies presumed that submarine groundwater discharges near the low water line. However, there is hardly any field data about the actual volumes of water circulating in the intertidal zone in such high energy systems. Accordingly, it is necessary to collect long time data about the dynamics and volumes of submarine groundwater discharge depending on tides, storm floods and seasonal groundwater recharge variations.
In this study, lysimeters and seepage meters were used to estimate the volumes of infiltrating seawater and exfiltration groundwater in the intertidal zone on the northern beach of Spiekeroog, a barrier island in the North Sea in Germany. The rates were assumed to be dependent on the beach morphology and tidal amplitudes. Therefore, a 3D-laser scanner was used over several campaigns to determine the change in the beach topography on short and medium time scales. Additionally, observation wells were installed and equipped with data loggers to monitor water levels and electrical conductivities with a high frequency over several tidal cycles.
The lysimeters and seepage meters showed net infiltration above mean sea level and net exfiltration below mean sea level. The exchange rates fluctuated between 1 and 12 liter per hour per square meter. Fresh groundwater influence could be located in one observation well near the low water line. Here, with about 22 mS per cm the measured electrical conductivity was constantly lower than in the surrounding wells (44 mS per cm). The groundwater level fluctuated depending on the tide. The beach topography changed because of wave, current and wind driven erosion and sedimentation processes and should be considered in numerical modelling as a mutable component. Planned tritium-helium measurements in the intertidal zone will help to improve the knowledge of groundwater pathways in the subterranean estuary and support the numerical models.

Code of abstract: T6.2.7
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.2. Monitoring of seawater influenced aquifers

Groundwater contribution in flooding events of Ostia Antica archeological site (coastal aquifer of Rome -Italy)

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KEY WORDS - Tiber Delta, groundwater-flooding, multilayers aquifer, groundwater salinization

ABSTRACT
In delta areas, the saturation level of fresh groundwater frequently shows depth of few meters below the ground. For this reason, the groundwater contribution often plays a crucial role in flooding.
The groundwater effect is even more marked in the reclaimed coastal areas, where some sectors are located at an altitude lower than sea level. If the groundwater level was not kept below the ground surface by dewatering, these areas would be always groundwater-flooded. This is the current situation of the archaeological site of Ostia Antica, where remains of the ancient roman city (VII century B.C.) near the coeval the Tiber mouth, are preserved; after exceptional rainfalls, the site is often largely flooded for several days. A hydrogeological investigation was thus carried out to recognize the aquifer response to local rainfall in order to prevent future flooding.
A program of water-table monitoring and groundwater electrical conductivity (EC) and temperature continuous measurements, coupled with the chemical analysis of major ions, started in 2014 on six measurement points, increased up to ten in the flowing months/years. Rainfall data were collected by the Ostia thermo-pluviometric station, belonging to Regional Hydrographic Service. Three core drillings, four meters deep, were also performed to improve the stratigraphic knowledge of the site and to collect soil samples for chemical analysis.
Results show the coexistence of two different overlapping groundwater circulations, separated by lower permeability deposits (clayey silt), according to the regional model of the Roman coastal multilayers aquifer.
The lower groundwater circulation consists of brackish water (EC at 25°C from 1500 to 4800 µS/cm), whereas the upper is fresh water (EC at 25°C from 400 to 1500 µS/cm) and is involved during the flooding events. However, the water table fluctuations of both circulations are influenced by the rainfall distributions; in dry periods, a possible hydraulic influence of the Tiber River is also identified. The resulting hydrogeological conceptual model has been validated by the results of hydro-chemical analysis distinguishing more than two water types according to the hydrodynamic setting.
Based on the results, additional suggestions can be provided in order to improve the efficiency of the drainage canal system specially designed for the water risks mitigation. Actually, the project of a new drainage system should take into account not only the runoff, but also the groundwater amount corresponding to the water-table rising.

Code of abstract: T6.3.1
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Possibilities of increasing fresh water abstraction on the karst island of Korčula (Croatia)

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KEY WORDS water supply, electric tomography, Adriatic karst island, salt/freshwater relations

ABSTRACT
Adriatic karst island of Korčula has one active pumping site with dug wells in the central-west part of the island (Blatsko polje), which supplies water to the central and western part of the island, while the eastern part of the island is connected to submarine water pipeline, and receives water supply from the mainland. Seaside tourism is the main branch of the island's economy, and the highest quantities of water are therefore required during the summer season, when the groundwater levels reach their minimum values. Seawater penetrates in wedge-like form from coastal zones, and reaches the Blatsko polje karst aquifer only in extreme hydrological conditions, when two or more dry years repeat in a role. This penetration happens mostly through fault and fractured zones which are highly karstified. In such cases, oversalinization of water was already recorded. Climate modelling predicted a gradual decrease in annual precipitation and increased irregularity of the rainfall with more frequent storm events, characterized by low infiltration and pronounced surface run-off. Therefore, it would be more favourable to disperse pumping wells on a larger area, if hydrogeological conditions allow it.
Western from the Blatsko polje, Vela Luka Municipality has shown some initial perspective, taking into consideration the geological structure and arrangement of permeable vs. impermeable rocks. Initial study was performed, which included the hydrogeological field inspection in search for submarine fresh water springs (vrulja), as well as a geophysical survey by four profiles (total length 2818 m) of electric tomography (ET), which has proven to be very useful in karst island aquifers research.
As a result, three prospective areas for fresh water intake were delineated and ranked according to their potentiality. Research should continue in one of the following directions: (i) detailed hydrogeological mapping and seismic refraction profiling in the areas deemed promising in the ET cross-sections and/or (ii) proceed directly to drilling of wells at a few favourable locations with constant hydrogeological supervision and state-of-the-art pumping tests including step-test with three steps and constant-test in the conditions of hydrological minimum, constant electroconductivity (EC) logging and water sampling and hydrochemical analyses.

Code of abstract: T6.3.2
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Characterization of the redox system of freshwater reservoirs below the back barrier island Spiekeroog

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KEY WORDS barrier island, freshwater lens, hydrochemistry, redox processes, sulphur isotopes, PHREEQC

ABSTRACT
Redox processes play an important role with respect to the hydrochemical evolution of freshwater reservoirs below barrier islands. The case of Spiekeroog Island showed, however, that it is often challenging to fully understand the redox system based on major ions only, and the application of further tools such as sulphur isotope analysis and geochemical modeling can be useful.
Spiekeroog Island is characterized by a ~45m thick freshwater lens underlying the old dunes in the western part and several smaller freshwater lenses in the younger eastern part. Hydrochemical sampling (i.e. major ion analysis and field parameters) was carried out at 14 medium to deep wells in the west (-6 to -43m above sea-level) in 2011, 2014 and 2016 and at three shallow wells in the east (1.5 to -1.5m asl) in 2016. Samples for DOC, δ^{13}C-DIC, δ^{34}S-SO_4^{2-} and δ^{34}S-H_2S and ^{3}H-^{3}He age dating were taken at all wells in September 2016. The hydrochemical data are used to understand the overall processes in combining shallow to deep, i.e. young to old groundwaters.
First results indicate that the redox system of freshwater reservoirs at Spiekeroog is characterized by oxic to sulfidic redox conditions. While surface-near groundwater shows oxygen and nitrate reducing conditions, elevated Fe(2+)-concentrations were detected in -10m asl only, indicating iron-oxide reduction. The absence of Fe(2+) in depths < -10m asl coincides with increasing H_2S concentrations, which could indicate the formation of iron sulfides. The stable sulphur isotope signatures indicate that sulphate is mostly not of marine origin (δ^{34}S-SO_4^{2-} values < 21 per mil) and that the redox cycle can be characterized as a closed system based on δ^{34}S-H_2S values which are increasing from -54.8 to +11.4 per mil within the upper zone of sulphate reduction (-6 to -10m asl). Surprisingly, δ^{34}S-H_2S values in depths < -30m asl were in the range -57.0 to -41.1 per mil which indicates open system conditions. The change from closed to open system may indicate considerable changes in the historical sulfate input, which has yet to be investigated.
A 1 dimensional PHREEQC simulation including redox processes and sulphur fractionation aids to improve the understanding and quantification of the observed processes.

Code of abstract: T6.3.3
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Direct determination of the rate of seawater intrusion with noble gases

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KEY WORDS Dating, Argon isotopes, tritium - helium, coastal Aquifer, seawater intrusion

ABSTRACT
This study deals with the determination of the rate of seawater intrusion with the novel analyses of noble gases. Several studies have recently tried to estimate the velocity of seawater intrusion by dating with radiocarbon and tritium. However, the interpretation of radiocarbon is complicated, due to water rock interaction, and the tritium content of recent recharging water is low and nearly constant and therefore limited in its use. Therefore, there is a need for new isotopic tools for this important issue.

The study was conducted in the Israeli coastal aquifer in a location where there are 5 boreholes in a cross section perpendicular to the shoreline, at distance of 30 to 700 meters. All these boreholes penetrated below the fresh-saline water interface and therefore allow sampling of the penetrating seawater for chemical and isotopic analysis, including for the first time those of noble gases (Ar-39, Kr-85, He-3) and other gases (CFC and SF6). Since all samples contain also component of fresh groundwater (~15%), it is important to understand the mixing ratios and calculate separately the age of each component which is not easily done. Therefore, the following ages should be regarded as preliminary only.

Ar-39 (whose half-life is 269 years) gave an age of ~270 years (50% of the current atmospheric values) for saline groundwater at distance of ~700 m, implying an horizontal intrusion rate of ~3m/yr. Preliminary analysis of radium isotopes also implies ages of ~200 years of groundwater at distance of ~700 meters. Similar rates were found in boreholes nearer to the shore by other methods, such as Kr-85 and Tr-He, where ages of less than 50 years were found in groundwater at distance up to ~200 meters. CFC also shows relatively high concentration indicating young ages in the first 200 m. It is interesting to note that in some places the ages of the shallow fresh groundwater were older than the deeper saline water.

Numerical simulations, taking into account the best estimate of hydraulic parameters of the Israeli coastal aquifer, gave somewhat similar rates of seawater intrusion, implying that these ages are reasonable. Thus, this preliminary research indicates that the analyses of noble gases could be the most suitable tool for determination of the rate of seawater intrusion.

Code of abstract: T6.3.4
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Distribution of groundwater age and fluctuation of NO_3-N concentration in groundwater in the reservoir area of Sunagawa underground dam, Miyako Island, Japan.

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KEY WORDS underground dam, SF_6, NO_3-N, groundwater age, environmental impact

ABSTRACT

Long term monitoring of NO_3-N concentration in groundwater had been carried out in the reservoir area of Sunagawa underground dam, which was constructed on Miyako Island, Japan in 1993, and SF_6 concentrations in groundwater were measured at 3 observation wells in 2012 and at 15 monitoring wells in 2015 to evaluate the environmental impact of construction of the underground dam.

NO_3-N concentration of long term monitoring well hardly changes from before construction of the underground dam until after construction. Average NO_3-N concentrations of 39 monitoring wells in 2009, 2012, and 2015 were 6.7, 5.6, 6.3mg/L respectively. 2012 was the drought year when NO_3-N concentration was the highest. Annual rainfalls in 2009, 2012, and 2015 were 1663, 2262, and 1848mm respectively, and nitrate loads on the surface farmland had not changed so much during these 6 years. These results show that the impact of the construction of underground dam on the underground environment was too small to influence the NO_3-N concentration in groundwater and the NO_3-N concentration is affected by the amount of precipitation after the construction of underground dam.

SF_6 concentration in 2015 was in the range of 7 to 9 pptv, and the groundwater age, which is retention period after recharge in aquifer, was in the range of 2 to 9 years. This result shows that there is a part where the groundwater circulation (from recharge to pump up) is relatively fast and the part where the groundwater circulation is relatively slow in the reservoir area. This was presumed to be due to the heterogeneous permeability of limestone aquifer. Average groundwater age of 3 monitoring wells was 4 years in 2012 and was 6 years in 2015. Groundwater age was relatively young in years with high precipitation. There was a weak correlation between the groundwater age and NO_3-N concentration (R^2=0.27). NO_3-N concentration was presumed to be relatively low due to high dilution of recharge water in the part where the groundwater circulation is relatively fast. Monitoring of groundwater quality should be done at water tank where pumped up water is stored because the average NO_3-N concentration at the monitoring well is different from the average NO_3-N concentration of pumped groundwater.

Code of abstract: T6.3.5
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Origins of groundwater salinity at Fishermans Bend, Australia: Evidence from groundwater ages, stable isotopes and tidal influences

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KEY WORDS coastal, groundwater, salinity, isotopes, tritium

ABSTRACT
A heterogeneous coastal groundwater system in southeast Australia was assessed using stable (^{2}H and ^{18}O) and radioactive (^{3}H and ^{14}C) isotopes to identify the origins of groundwater salinity. The spatial distribution of groundwater salinity (electrical conductivity values ranging from 0.52 to 36.15 mS/cm) was examined in 38 boreholes across 240 ha of the Yarra Estuary at Fishermans Bend, Melbourne, along with high-resolution geological, isotopic and hydrogeological (tidal) data. This allowed assessment of different salinity sources and mechanisms for salt evolution. Three distinct horizontal salinity profiles were observed with varying distance from the tidally-driven Yarra River, along a 300m transect. Salinity appears to be predominantly controlled by lithology, with an inland sandy aquifer yielding lower salinity groundwater (0.52 to 5.78 mS/cm), a transitional sandy-clay unit yielding brackish groundwater (10.55 to 15.31 mS/cm), and a clay aquitard adjacent to the river yielding saline groundwater (32.92 to 36.15 mS/cm).

Sodium/chloride ratios range from 0.46 to 11.27 (0.46 to 0.50 in the transitional material, 0.51 to 0.55 in the saline clay aquitard, and 0.59 to 11.27 in the relatively fresher sandy aquifer), indicating salts are predominantly marine in the transitional and clay units, where EC values are greater than approximately 11 mS/cm. Groundwater across the transect shows increasingly marine-like stable isotopic signatures, with $\delta^{18}O$ and $\delta^{2}H$ values of -4.71‰ and -25.60‰ in the sandy aquifer indicating meteoric water, -3.71‰ and -21.08‰ in the transitional unit, and -3.12‰ and -18.27‰ in the saline clay aquitard. Tritium data also vary across the transect, with typical Melbourne TU values observed in the sandy aquifer (1.79 TU) and transitional material (2.02 TU), and significantly lower activity in the saline aquitard (0.25 TU), indicating minimal mixing with modern water in this unit, possibly sourced from a meteoric component of the adjacent Yarra River. As the area at Fishermans Bend is undergoing large-scale urban development, the origins of groundwater salinity and the delineation of the salt-fresh water interface are critical for correct designation of beneficial uses of the groundwater for its protection.

Code of abstract: T6.3.6
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Water-rock interaction in Eocene aquifers of Qatar: Hydrochemical evidence of dedolomitisation driven by gypsum dissolution.

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KEY WORDS - Hydrochemistry, karst, water-rock interaction, gypsum dissolution, dedolomitisation

ABSTRACT

The Qatar peninsular comprises a gentle N-S oriented pericline, up to 65 km wide, that extends some 180 km from the northern coast of Saudi Arabia northward into Arabian Gulf. The modern climate is very arid, with high rates of evaporation and a mean annual rainfall ranging from <50 mm in the south of the country, to >100 mm in the north. Most drainage is endorheic, and rare intense rainfall events recharge the shallow aquifer via overland flow to low-relief terminal depressions. Recharge is facilitated by fractures and karst features developed over the extended (c.30 Ma) period of subaerial exposure of the Eocene bedrock.

Groundwaters are hosted in largely dolomitic Tertiary aquifers, which include the Paleocene to Lower Eocene Umm er Radhuma and overlying Lower Eocene Rus Formation, with the Middle Eocene Abarug limestone forming a locally important aquifer in the south west. Two major hydrogeological provinces have been recognized, reflecting the distribution of facies within the Rus Formation. In the south of the country the Rus is subdivided by a unit of gypsum and clays which is up to 50 m thick. This confines the underlying Lower Rus and Umm er Radhuma aquifers, which are fed by recharge from outcrop areas to the south and west within Saudi Arabia. To the north of Qatar gypsum was either not deposited within the Rus formation or has since been largely dissolved, and the aquifers are in hydraulic continuity.

This study uses major ion chemistry data for ground waters from 76 wells distributed across Qatar to characterize water-rock interaction in the Eocene aquifers. Chloride concentrations show clear evidence of salinisation adjacent to the coast due to mixing with adjacent seawater from the Arabian Gulf. Fresher waters develop in the interior of the peninsula in the northern aquifer (>2 mMol Cl^-), compared to those in the south (>15 mMol). Using Cl^- as a conservative tracer for mixing with seawater, we calculate concentrations of Ca^{2+}, Mg^{2+} and SO_4^{2-} that are derived from water-rock interaction. All waters are significantly enriched in sulfate, but this is most marked in the southern province, likely reflecting the abundance of gypsum in the subsurface. Sulfate enrichment is accompanied by elevated levels of calcium. Wells in the Abarug limestone more limited enrichment and a 1:1 molar ratio of rock derived SO_4^{2-}, Ca^{2+}, but across much of the country the molar ratio is significantly higher, often reaching 2:1 and suggesting a sink for Ca^{2+}. In combination with an enrichment in Mg^{2+} in waters within the dolomite aquifers, this provides clear evidence for replacement of dolomite by calcite (dedolomitization), driven by the release of Ca^{2+} from gypsum dissolution. Whilst current rates of gypsum dissolution and dedolomitisation are limited by the arid climate, this process is likely to have been more active during pluvial periods and likely played a role in karst development.

Code of abstract: T6.3.7
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Estimate of the amount of freshwater lens and fluctuation of thickness of freshwater in Tarama Island, Japan.

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KEY WORDS freshwater lens, freshwater-saltwater interface, electromagnetic survey, continuous monitoring, upconing

ABSTRACT
Electric conductivity of groundwater was measured every 1 m of depth in wells on Tarama Island, Japan to clarify the thickness of the freshwater lens. In addition, electric terrain conductivity was measured by electromagnetic surveys. As a result, it was clarified that the thickness of the freshwater lens (electric conductivity less than 200 mS/m) on Tarama Island was 0 - 7.2 m at 12 wells. In addition the freshwater-saltwater interface depths that were estimated to be 14 - 23 m by electromagnetic surveys corresponded to depths where electric conductivities were 1,840 mS/m. There was a high correlation (R^2 = 0.9) between depths where electric conductivity of groundwater was 200 mS/m and the depth of freshwater-saltwater interface estimated by electromagnetic surveys. From these results, the thicknesses of freshwater were estimated at 7 wells, where the thickness of the freshwater lens could not be determined by measurement of electric conductivity in groundwater because the bottom of borehole was upper than freshwater-saltwater interface. Finally, the amount of the freshwater lens was estimated to be 6.8 million m^3.
Electric conductivity of groundwater was measured continuously at EL.0m, -5m, -8m, -11m, and -14m respectively in a borehole in the center of Tarama Island to clarify the fluctuation of the freshwater lens. Electric conductivity was fluctuated by the influence of the tide. The influence was removed by averaging measurements by 25 hours. However, the fluctuation of the irregular tide brought by the typhoon etc. was not able to be removed. The thickness of the freshwater lens was presumed from the electric conducitivity. The thickness of the freshwater lens was about 8m from November, 2011 to September, 2012. The thickness of the freshwater lens increased by 1.6m when Typhoon No.17 brought heavy rains to the Tarama Island at the end of September 2012. On the other hand, the thickness of the freshwater lens decreased by upconing when the fresh groundwater was pumped. These results show that the continuous monitoring of electric conductivity was useful to clarify the fluctuation of the thickness of a freshwater lens.

Code of abstract: T6.3.8
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Field evaluations of new monitoring method for temporal change of freshwater-saltwater interface location

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KEY WORDS - Freshwater-salt water interface, InterfacEGG, temporal monitoring, salt water intrusion, coastal aquifer

ABSTRACT
Management of coastal aquifers is becoming increasingly important with the growing prospects of global climate change. Excessive pumping of coastal aquifers often results in saltwater intrusion and saltwater up-coning. Therefore, many countries have installed monitoring wells along coastlines, especially in the vicinity of agricultural and urban areas. Most of the coastal monitoring wells are equipped with a single sensor measuring water pressure, temperature and/or electrical conductivity at a certain depth in the well. However, such single-depth measurement methods can only give us the information that the freshwater-saltwater interface is either above or below the sensor. A new method has been developed using a probe, an "interface egg", to monitor temporal changes in the position of the freshwater-saltwater interface. The probe is designed to float on the interface and thus can move up and down along with the movement of the freshwater-saltwater interface. Even in cases where there is a relatively wide transition zone between fresh water and salt water, the probe can give us the real time location of the upper boundary of the interface, which is critical for saltwater intrusion monitoring. The temporal change in the thickness of the freshwater lens and the transition zone can be calculated using a combination of another interface egg and depth-fixed sensors. This method has been tested and validated at monitoring wells in Jeju Island, Seocheon, Pusan, Korea and Oahu island of Hawaii, USA. It can be utilized as an early warning system for saltwater intrusion and/or freshwater decline when the probe is integrated with a predictive numerical model and a remote communication technology.

Acknowledgement: This research was supported by the 'Development of real-time surveillance model for saltwater intrusion in coastal aquifers' (GAIA project 2016000530004) of MOE, Republic of Korea.

Code of abstract: T6.3.9
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Hydrogeological mapping of the island of Öland, Sweden, with SkyTEM

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KEY WORDS SkyTEM, Sweden, island aquifers, seawater penetration, Öland

ABSTRACT
In 2016 the Geological Survey of Sweden (SGU) conducted a total of 800 km² airborne transient electromagnetic survey (ATEM) on the island of Öland situated in the Baltic Sea 10 km from the mainland of Sweden. The focus of the study was hydrogeological, and the main purpose to find and delimit new groundwater resources, and to map the depth to the interface between fresh and saline groundwater.
Inhabitants and visitors on the Island encounter major seasonal problems during the summer with the supply of drinking water. The cause of shortage is a combination of low groundwater recharge and groundwater reservoirs located in areas with thin soil layers and in the fractured sedimentary bedrock with a limited reservoir volume.
The thin soil coverage, shallow bedrock and draining for agricultural purposes, causes most of the precipitation not to form groundwater but to run off to the sea. In addition to shortage of aquifers it is fairly common with saline groundwater at shallow depths (20-30m b.s.l.).

The SkyTEM survey on the Island of Öland shows that the method is well suited for this kind of geology. The result indicates areas where the potential for groundwater extraction is higher than known before. The new data also reveal new and previously unknown information regarding the subsurface geology on the island down to approximately 150 m depth. With the results the geological survey has been able to point out areas with a high potential for groundwater withdrawal, saltwater depth-maps, localizing faults and to update soil depth maps.

The results are of importance for the municipality of Gotland when localizing pumpingwells to increase the total amount of groundwater withdrawal especially during the tourism season.

Code of abstract: T6.3.10
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Long term groundwater quality evolution in arid climate and intense exploitation context: case of the coastal basaltic aquifer of Djibouti.

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KEY WORDS - basaltic aquifer, hydrochemistry, stable isotopes, residence time, sustainability, salt intrusion

ABSTRACT
In the very arid conditions of the Republic of Djibouti (Eastern Africa), basaltic aquifers represent the only source of water that can be used to fulfil drinking and agriculture water needs. Due to a strong increase in the population and to the lack of any other economically affordable alternative resource, the basaltic aquifers from the coastal regions are still very intensively exploited. Unfortunately major drawbacks are now appearing like a decrease in the groundwater levels and a progressive inland evolution of the sea water wedge. The object of this study is to compare the present time status of the groundwater quality with a reference study carried out on the same region in the 2003-2004 (Bouh, 2006) and to evaluate the intensity of the perturbations and alterations in terms of quality, groundwater origin and renewability potential. In this purpose a new sampling was carried out in March 2017 in order to investigate groundwater for physico-chemical parameters, hydrogeochemical tracers, trace elements, stable isotopes of the water molecule, tritium and radiocarbon. Preliminary results tend to indicate a strong evolution in the main ionic components associated with the development of the marine water intrusion shown by the EC and alkalinity modifications. Investigations in relation with the groundwater residence time potential evolutions will now be carried out in order to evaluate the dynamics of modifications and their potential impacts towards groundwater mining processes.

Code of abstract: T6.3.11
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

Mapping and evolution of hydrochemical water types in Maputo coastal aquifer

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KEYWORDS – Hydrochemistry, water facies, saltwater-intrusion, stable isotopes, recharge

ABSTRACT

Maputo and its surrounding area experienced a significant increase in population since the 1990's which has intensified groundwater exploitation of the coastal aquifer system. Groundwater presents locally high salinity and seawater intrusion is recognized as one of the contributing factors. Regional groundwater samples were collected, analysed and classified into hydrochemical water types – clusters of water with similar chemical composition. Spatial distribution of water types was used to determine qualitative variation in groundwater, chemical mixing zones, water facies evolution and understanding of flow paths. The local recharge and discharge mechanisms were also used to support explanation of water facies evolution. A geographic information system multi-criteria decision analysis (GIS-MCDA) was used to classify different zones and their recharge potentials, based on hydrogeological properties and land uses. Recharge rates were calculated through a root zone water balance method. Results indicate values up to 30% of precipitation goes to groundwater recharge, with important contribution from extreme daily events. Higher rates occur within aeolian sediments covered by shrubland and lower rates in agricultural areas, mainly due to high evapotranspiration. Groundwater shows spatially varying chloride concentrations and electrical conductivity (EC) values. Fresh water types are predominantly found in recharge areas while brackish and saline water types are located near the coast. Dominant ions in groundwater samples are Na and Cl. An active chemical mixing zone is identified at the centre of the study area. Maximum EC values are found in densely populated areas close to the coastline where groundwater abstraction is high and uncontrolled. This study suggests two mechanisms are responsible for the high salinity of groundwater. Seawater intrusion is the major contributor of high salinity values in the semi-confined aquifer, while high evaporation rates is likely to play a major role in the phreatic system. Managed aquifer recharge (MAR) is a potential mitigation measurement to enhance recharge and improve water quality in the area. An ongoing isotopic and hydrochemical assessment will provide further insights of the local hydrochemical processes.

Code of abstract: T6.3.12
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.3. Sea-aquifer relationship – using new and old tools

New guidelines to describe seawater intrusion process: the experimental Argentona field site

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KEY WORDS --- mixing zone, alluvial facies, multi---scale approach, hydro---geochemistry, hydro---geophysics.

ABSTRACT
Seawater intrusion is a widespread process that is occurring with increasing frequency in coastal aquifers due to the higher demand of groundwater resources. The characteristics of the freshwater---seawater interface (FSI) and its dynamics are strongly conditioned by the lithology and, among others, the typology of the discharge, density contrasts and tides. To increase the understanding of seawater intrusion system, a multidisciplinary and multi---scale approach is necessary to build robust conceptual and numerical models.
For that purpose, we have developed an experimental field site in a coastal alluvial aquifer at the mouth of a temporary stream in the Maresme coast line (Barcelona, Spain). This area is characterized by the discharge of a ephemeral flow (Argentona stream) and the Mediterranean seawater intrusion for more than 50 years due to over---pumping. The aquifer is formed by unconsolidated heterogeneous and polygenic alluvial sediments ranging from very fine to very coarse grained sand with discontinuous interfingering lenses of gravel and silt. All this sediments has above 20 m thickness and are overlying a weathered granitic basement.
The proposed methodology consists in the installation of several boreholes drilled perpendicular and parallel to the shoreline, at various depths to reach different conductivity areas along the mixing zone. Several geophysical techniques have been performed from the surface and within the boreholes in order to characterize the salinity gradient and distinguish sedimentary facies. Furthermore, a fully hydrochemical investigation was carried out to define the initial groundwater composition using TOC/DOC measurements, mayor and minor elements analysis, nutrients identification and radium and radon isotopes quantifications. Also lithological description, sedimentological correlation and geochemical analysis of the cores obtained after drilling (DRX, CEC, acid digestions) were integrated to fully characterize the initial stage of the experimental site. This integrated multidisciplinary and multi---scale methodology will allow understanding the local FSI dynamics and give new guidelines for the study of seawater intrusion processes in many other sites

Code of abstract: T6.4.1
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

A comprehensive approach to the knowledge of the coastal carbonate aquifers of Adriatic and Ionian Seas

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KEY WORDS - Coastal Carbonate Aquifer, seawater intrusion, geodatabase, Ionian Sea, Adriatic Sea

ABSTRACT
The increasing groundwater exploitation and contamination risks due to the progressive population growth in coastal areas are emphasized in the case of carbonate coastal aquifers (CCAs), the peculiarities of which, especially in the Mediterranean basin, constitute a scientific matter of worldwide relevance.
The CCAs of the Adriatic and Ionian coasts not only ensure the socio-economic development of the populations but feeds with their spring waters valuable wetland and coastal environments with relevant and highly positive effects on ecosystems. The groundwater resources of CCAs are highly vulnerable, especially if affected by karstic phenomena, to the quality and quantity degradation phenomena, not only for the increasing water demand and the decreasing recharge due to climate changes but also in relation to the sea level changes and the pollutant loads due to the contamination occurred in the whole hydrogeological basins.
The aim of this study is to offer a systematic and synoptic view, useful for knowledge, management and forecast purposes, contributing to assure enduring availability of high quality groundwater, conciliating water demand satisfaction with the ecological needs of coastal Adriatic and Ionian environments in which the role of groundwater is very important. A geodatabase, collecting information for all carbonate aquifers present along the Adriatic and Ionian coast, have been created. At the core, there is a Geographic Information System, in which are placed the spatial information regarding the geology of aquifers, hydrogeological and geochemical features, together with specific information concerning groundwater use of CCAs. The added value of this database is the availability of a wide bibliography related to CCAs, together with a schematised summary of key information realised considering available information in the whole geodatabase.
Starting from this idea, the cooperation between hydrogeologists experts of different areas, have enabled to focus on some specific areas of peculiar hydrogeological interest, as for the CCAs of Apulia (SE Italy), South-western Slovenia, Western and South Croatia, Montenegrian coast (Boka bay) and Western Greece.

Code of abstract: T6.4.2
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Integrated assessment of hydrological impacts of potential future scenarios of climate, land use change and Sea Level Rise on a coastal Mediterranean aquifer. The Plana Oropesa-Torreblanca aquifer.

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KEY WORDS Global change; seawater intrusion; coastal aquifer; climate change, land use change

ABSTRACT
Any change in the components of the water balance in a coastal aquifer, whether natural or anthropogenic, can alter the dynamic equilibrium between fresh water and salt water modifying the seawater intrusion process. Climate change and Land Use and Land Cover (LULC) change might significantly influence the availability of water resources in the future. The interaction between fresh water and seawater in these coastal systems demands an integrated analysis of quantity and quality issues to obtain an appropriate assessment of the salinization process using density-dependent flow solutions. The aim of this research paper is to propose a method of integrated analysis of the potential impacts of future climate scenarios, land use change and Sea Level Rise (SLR) in a coastal aquifer. It is based on a sequential coupling of rainfall-recharge models, agronomic water requirements and irrigation returns models (for the aquifer and its neighbours that feeds it), and a density dependent aquifer approach (which couples the solutions of the flow and transport estimates in each time step). The models were defined using available historical data (1973-2010). These models allow testing the conceptual approximation of aquifer behaviour and to perform a sensitivity analysis regarding (previously defined) potential future global change scenarios of rainfall recharge, lateral flows of the hydraulically-connected neighbouring aquifer, agricultural recharge (taking into account expected future land use changes) and SLR. This methodological analysis could be valuable to improve our knowledge about an aquifer and so comprise a tool to design sustainable management strategies. It was applied to the Plana Oropesa-Torreblanca aquifer.

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Code of abstract: T6.4.3
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Water Management in Coastal Areas under the Conditions of Climatic and Demographic Change at the German Coast

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KEY WORDS - water management, climatic change, sea water intrusion, density-driven flow, groundwater modelling

ABSTRACT

To ensure a sustainable water supply in coastal areas and to effectively plan future long term investments in the water supply infrastructure, it is necessary to comprehensively analyse the effects of climatic and demographic change on coastal aquifer systems. Sea level rise due to climate change, resulting in salt water intrusions into aquifers, modified river flow conditions, and altered precipitation patterns are likely impacts on the water supply, whereas peak demands are expected especially during summer, e. g. due to increased tourism at the coast, irrigation in agriculture and cooling water demand in industry. On the other hand, the demographic change with a general decline in population and a rural depopulation may cause a decrease in water demand. This project aims at identifying existing and expected impairments on both supply and demand and on deriving scenarios of climatic and demographic change affecting the water supply.
Focus of this presentation is on modelling of groundwater flow using the code "distributed density-driven flow" (d^3f++). Two regions in Germany, each facing specific water supply problems, are chosen as investigation areas: Sandelermöns at the North Sea and the Elbe-Weser triangle. Various scenarios are derived for each site and their consequences are evaluated by means of groundwater modelling. The three-dimensional hydrogeological model for the Sandelermöns catchment area extends over ca. 1,000 km^2 and has six units, representing Pliocene to Holocene sediments. Impacts of nine future scenarios on the groundwater system were calculated, including change in fluid volume, impact of groundwater recharge, drainage and extraction wells and change in groundwater salinity, thus facilitating an identification of the crucial parameters. For the Elbe-Weser triangle, a two-dimensional model of 9 km length and five Quarternary and Tertiary units as well as a three-dimensional model with three Quarternary and Tertiary units were employed to investigate three different scenarios each. Some of the scenarios lead to an elevated groundwater table and a saltwater intrusion into some of the extraction wells, while others show no major influence of climate change on the groundwater table or the salinity in the extraction wells. In a next step, adaptation strategies for the water supply will be formulated, including possible options to mitigate sea water intrusions.

Code of abstract: T6.4.4
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

ACVM (Aquifer Comprehensive Vulnerability Mapping) - A new tool for assessing potential impacts on the sustainability of coastal aquifers and habitats.

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KEY WORDS: Coastal aquifer vulnerability, Sea water intrusion vulnerability map, sea level rise and its impact on groundwater, groundwater quality defence, coastal aquifer management tools

ABSTRACT
Human activities in the coastal zone often depend on groundwater resources but have the potential to discharge pollutants into the environment, infiltrating soils and eventually entering groundwater resources. At the same time, coastal aquifers are usually in hydraulic connection with the sea, making them susceptible to the phenomenon of salt water intrusion. This phenomenon can be worsened by climate change, since a modest increase in sea levels can result in significant salt water intrusion and subsequently a decrease in groundwater quality. Therefore, coastal aquifers are subject to contamination from both land-based sources and salt water intrusion and are also vulnerable to the impacts of climate change.
Vulnerability mapping is a tool that can be used to illustrate how the intrinsic physical properties of an aquifer protects it from an external threat that can potentially decrease groundwater quality. The ACVM (Aquifer Comprehensive Vulnerability Mapping) method is a new tool that can describe simultaneously many aspects of aquifer vulnerability using only one parameter. This new method is easy to use and can be applied with inexpensive data.
ACVM was conceived, developed and applied in the area of Ghar El Melh in Tunisia in the context of the Global Environment Facility (GEF)/UN Environment Programme (UNEP)/Mediterranean Action Plan (MAP) Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem (MedPartnership Project, 2009 - 2015). UNESCO's International Hydrological Programme (IHP) was responsible for the execution of MedPartnership Subcomponent 1.1 on 'Management of Coastal Aquifers and Groundwater', which provided the framework for this activity.
Vulnerability maps prepared with the ACVM method show the distribution of the intrinsic physical properties that can protect an aquifer against external threats to its groundwater quality, over the short and long terms. Moreover, it is possible to translate this parameter into management recommendations that decision makers can use to help them understand how activities can impact the sustainability of coastal aquifers and their related habitats.
The ACVM method establishes a new conceptual approach to evaluating aquifer vulnerability and could be replicated at other coastal aquifers to demonstrate its potential for widespread use.

Code of abstract: T6.4.5
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Assessment of seawater intrusion problems (status and vulnerability) at different spatial scale. Contribution to the analysis of coastal aquifers in accordance with the WFD.

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KEY WORDS Seawater intrusion; coastal aquifer; lumped index; vulnerability; global SWI assessment

ABSTRACT
In this research we propose a method to perform a mixed lumped-distributed analysis of the status and vulnerability of coastal aquifer to seawater intrusion (SWI). We intend to apply an indices-based method to assess and summarize problems in coastal aquifers due to chloride pollution at different spatial scale, moving from maps to 2D conceptual cross sections and lumped indices. They intend to help to identify coastal groundwater (GW) bodies in risk of not achieving good chemical status in accordance with the WFD (2000) and to identify possible management strategies to reduce existing impacts. It may be even applied to cases where a reduced number of data is available. The method does not require complex modeling approaches and has been implemented in a GIS tool that helps to apply it in other cases. The historical evolution of the indices can be used to assess resilience and trends respect to SWI problems. It can be also useful to compare intrusion significance in different GW bodies and temporal periods.
The global assessment will be based on two indices, the MART index, which summarizes the global significance of the SWI phenomenon, and the L_GALDIT for a lumped assessment of the vulnerability to SWI. The MART index assesses global intrusion status in coastal aquifers by providing information about the total mass of chloride coming from the sea. It can be obtained by simple linear operations of storages and concentrations deduced from aquifer geometry, specific yield fields and hydraulic head and chloride concentration maps. Those maps can be deduced by using different modeling approaches (eg. simple interpolation methods, density dependent flow models). A 2D representative cross section can be also deduced to summarize the mean geometry (penetration and thickness of the affected area) and intensity of the intrusion. An analogous procedure is applied to the GALDIT index to summarize the vulnerability of the aquifer to SWI at different spatial scale (maps, 2D section and global index). In this case we combine vulnerability maps with storages instead of chloride maps. While MART index is calculated using only physical variables, L_GALDIT employs weighted qualitative characteristics. The combination of them can help to summarize SWI problems.
This work has been supported by the GESINHIMPADAPT project (CGL2013-48424-C2-2-R)

Code of abstract: T6.4.6
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

DEVELOPMENT OF GROUNDWATER VULNERABILITY MODEL FOR THE PURPOSE OF REGIONAL SPATIAL PLAN OF MONTENEGRIN COSTAL AREA

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KEY WORDS - vulnerability analysis, groundwater, coastal area, protection, urbanization

ABSTRACT

Due to the complex and specific hydrogeological characteristics and water management problems of coastal area of Montenegro, new approaches are required in its management. It is necessary to expand the existing, and develop new methods of the system analysis so that it meets the specific properties of coastal areas.

Within the Coastal Area Management Programme (CAMP) on the basis of the Protocol on Integrated Coastal Zone Management in the Mediterranean, in the context of implementation of analysis for the purposes of spatial planning and environmental protection, was carried out an analysis of the general vulnerability based on the vulnerability of individual segments of the environment.

For the needs of the referred program, a vulnerability model of groundwater has been developed, as one of the processed segments of the environment, which should from its point of view provide insight into adequacy of coastal areas for urbanization. The method of groundwater vulnerability analysis is based on knowledge of the hydrogeological properties of rocks, spatial distribution of zones of sanitary protection of water sources, as well as the presence of peloids and mineral water. The main objectives of this analysis is to define aquifer zones, particularly springs for water-supplying, as well as deposits of peloids and thermal mineral water, in order to protect it from further devastation during the construction and urbanization of coastal areas.

With this vulnerability model and also using GIS platform, hydrogeological characteristics of the coastal aquifer become understandable dataset for planners to manage conflicts of groundwater protection and urbanization.

Analysis of general vulnerability with regard to the groundwater vulnerability model within the CAMP program provides some recommendations for future regional spatial plan for the coastal area of Montenegro.

Code of abstract: T6.4.7
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Evaluation of management rules for the sustainable management of freshwater lenses using script-based models

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KEY WORDS coastal aquifers, freshwater lenses, numerical modelling, groundwater management

ABSTRACT
Fresh groundwater in islands is stored in lenses that form fragile resources of potable water, and over-abstraction can quickly lead to significant salinization. Numerical models are effective tools to support the sustainable management of freshwater lenses, but standard groundwater modelling codes are not well-suited to test the effectiveness of operational management processes that entail a dynamic response to changing state indicators of the resource, such as water level or salinity. This contribution presents the results of a numerical model that was constructed using the FloPy library, which enables the execution of a MODFLOW-based model in a Python programming environment. The objective of the model was to evaluate future scenarios of adaptive management during drought that involves adjusting the abstraction rates depending on measured salinity values on the island of Bonriki, Kiribati. A calibrated SEAWAT model was used as a basis, for which the 30-year future simulation period was subdivided into 3 month time intervals. Using a Python program, the salinity of the abstracted water is evaluated after each 3 month period, and based on the management rules provided, the abstraction rates for the next 3 months are decided and carried forward. In this approach, the modeller only specifies the pre-defined rules for the management scenario in the program, and all the pre-and post-processing of model files is fully automated. This enables the rapid evaluation of different to management plans, or variations of a plan, and avoids the need for tedious preparation of input and analysis of output files. In this case study, a rainfall-based index and salinity changes in the freshwater lens were used as indicators for a drought period, and during these, pumping rates of individual wells were reduced as long as a salinity threshold was exceeded. The results of the models were used to recommend a set of operational rules to maximise the availability of water without causing detrimental salinization of the freshwater lens during droughts.

Code of abstract: T6.4.8
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Groundwater management in coastal zones and on islands in crystalline bedrock areas of Sweden

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KEY WORDS groundwater, coastal areas, islands, water supply, fractured bedrock

ABSTRACT
Groundwater problems in coastal regions are usually not associated with the sparsely populated shores of water-rich Scandinavia. However, the combination of geology and the specific conditions of water usage create challenges even there. Along the Swedish coast, much of the groundwater occurs in fractured bedrock or in relatively small, shallow, and isolated quaternary sedimentary formations. Those aquifers cannot provide water to larger permanent settlements and have thus previously not received much attention from water authorities or researchers. However, of the 450,000 private wells in Sweden, many are located in coastal areas or on islands, creating pressure on groundwater resources in summer months as periods with low or no natural groundwater recharge.
Here, we present the results of an investigation on the "Koster" archipelago which forms a microcosm of coastal zone groundwater problems in Sweden. Koster's geology is dominated by fractured, crystalline bedrock with occasional shallow quaternary deposits in between. With around 300 permanent residents, and up to 6,000 summer guests in peak holiday season, the existing water supply based on 800 private wells is at its limit. Water availability forms an obstacle to future development and the current mode of operation is unsustainable.
As there are no observation wells on the islands, we used approximately 220 of the 800 wells (65% dug and shallow, 35% drilled and up to 120m deep) for our monitoring. Additionally, water samples were collected by property owners on four occasions (spring, summer, fall, and winter). All samples were analyzed for electrical conductivity, major ions, and metals. Groundwater levels, in situ measurements of physicochemical parameters, and borehole logs of electrical conductivity and temperature were conducted for around 80 wells. Hydraulic head, electrical conductivity, and temperature were monitored continuously at 10 locations.
The case is interesting as studies dealing with saltwater intrusion in fractured (bedrock) aquifers are rare, thus offering the possibility to connect state of the art research with practical management questions at the science-society interface. Here, we present monitoring results over an entire hydrological year and how these can better inform the municipalities' decision-making process.

Code of abstract: T6.4.9
Type of presentation: Oral presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Societal use of submarine groundwater discharge –examples of an underresearched water resource

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KEY WORDS submarine springs, submarine groundwater discharge, water resource

ABSTRACT
Fresh submarine groundwater discharge (fresh SGD) is increasingly recognized as relevant scientific topic in the context of local and global scale land-sea matter fluxes. However, its use as a water resource has been nearly entirely neglected by scientific studies. Here, we present examples from a variety of places and around the world where fresh SGD is used as water resource by the local population. Its obvious use as drinking water is complemented by use for hygiene (bathing, laundry), agriculture (irrigation, cattle feeding), but also its effects are used e.g. by fishermen and dive schools or they are relevant for ship navigation. In addition, fresh SGD locations often play a substantial role in the spiritual life of the local communities.
Examples of fresh SGD use are Lombok (Indonesia) where fresh SGD is used for drinking, on Kode Island (Fiji) it is used for bathing, and in Kiveri (Greece) for irrigation. Vrulja Bay (Croatia) is known among divers for its species richness associated with the local submarine spring (which is the type locality for submarine springs, called “vrulja” among karst geologists), and already Alexander von Humboldt noted that Manatees gathered around a submarine spring in Cuba and were hunted by fishermen. Fresh SGD, freshwater in the ocean, is likely to inspire spiritual thoughts, and it is e.g. part of Hawaiian legends, gives insight about the History of Tarento (Italy) and is used to bless 2 million visitors of an intertidal spring each year on Bali.
However, fresh SGD is sensitive to sea level rise, and coastal groundwater pumping. Submarine springs off Bahrein, which were used by divers to deliver freshwater to the city as drinking water until the 1950ies have subsequently dried out because of terrestrial groundwater pumping. It is important to recognize the relevance of fresh SGD to local communities before taking management decisions that could endanger the existence of this hidden water resource.

Code of abstract: T6.4.10
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Hydrogeological research for water-source heat pump utilization in Babin kuk peninsula (Dubrovnik, Croatia)

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KEY WORDS water-source heat pump, borehole positioning, structural features, hydraulic parameters

ABSTRACT
The study was conducted in order to determine optimal locations for the positioning and design/development of extraction and injection wells with total capacity of 50 l/s which will be used in a water-source heat pump system of a hotel. Since the location is in vicinity of the sea, the idea was to extract sea water. The research was carried out in three phases. (1) Initial hydrogeological prospection was done by mapping structural elements and determining the positions of tension fractures in the rock mass, representing the most promising structural element to ensure favorable hydraulic properties of the future wells. The main obstacle in positioning the boreholes was the size of the available terrain. Drilling of the first piezometer had demonstrated the assumption about the favourability of tensional fractures as a target. (2) Borehole cores of the two drilled piezometers were analyzed and main hydrogeological and engineering geological properties were determined (3) Locations of two abstraction wells and two reinjection wells were determined. Abstraction wells were positioned on the same discontinuity further from the coastline, while two reinjection wells were placed on another discontinuity recognized at the ground surface closer to the coastline. Pumping tests were conducted on all wells. Maximum wells capacity was 170-420 L/s, depending on the well. However, constant pumping of such high quantities would cause capacity reduction of all wells. It can be concluded that the positioning of the wells was adequate since every single well has high enough yield to supply water for projected heat pump system by itself. Wells further from the coastline are more favourable to serve as abstraction wells since water temperature is more constant. Although water temperature will certainly experience some seasonal variations, it will be far less pronounced than in the case of direct intake from the sea, increasing the seasonal performance factor of entire heat pump system.

Code of abstract: T6.4.11
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Anomaly of Hydraulic heads at deep region in Pleistocene sedimentary soft rock area, Japan

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KEY WORDS - Coastal area, Soft rock, Deep groundwater, Groundwater age, Hydraulic head, Groundwater flow system

ABSTRACT

The hydraulic head at total seven depths from surface to a depth of 1143 m were measured by using double packer system at the drilling hole, DD-1, which locates approximately 300 m from a shoreline at Horonobe, Hokkaido, Japan. The study site is covered by alluvial deposits to a depth of 100 m. At deeper than 100 m, soft Pleistocene sedimentary rocks dominate. For example, sandy geologic cores throughout the drilling interval collapsed in the core barrel. On the other hand, silt and clay layers stood themselves.

Hydrogeologic condition in the area has already reported by Ikawa et al.(2014). From the Cl-, hydrogen and oxygen stable isotopes in pore water squeezed from geologic cores, hydrogeology can be classified into three regions: (1) aquifers and impermeable layers (from surface to a depth of 500 m), (2) Diffusion zone (from 500 to 800 m), (3) Connate water zone (deeper than 800 m). The Cl- concentration from surface to a depth of 500 m were less than 3,000 mg/L except one. Below 500 m depth, it increased in depth direction (diffusion zone) and reach to almost same to sea water at a depth of 800 m (connate water zone).

In this study, we carried out the perforations at seven depths, 214, 306, 476, 613, 715, 943 and 1143 m in the DD-1. By using double packers system, hydraulic head at the considered depths were measured. As the result, the hydraulic head did not change at region shallower than 306 m depth. At deeper than 476 m, it increased gradually to: + 4 m at a depth of 476m depth, +15 m at 943 m depth. Finally it attains to be + 50 m at 1143 m depth. The chemical properties of pumped water and pore water from the depth of 800 m to 1200 m show almost same to sea water. The groundwater age in the connate zone is, therefore, considered to be same to the geologic formation at sampling depth, more than 1.3 million years. Although clay layers distributed around 900 – 1000 m depth, it may be difficult to maintain such high pressure for an million years. The authors suspect the effect of non-Darcy flow to form such hydraulic barrier.

Code of abstract: T6.4.12
Type of presentation: Poster presentation
Topic: T6. Coastal and Island Hydrogeology
Session: T6.4. Management of groundwater resources of coastal aquifers

Assessment of coastal Aquifers in Latin America and Climate Change: The WaterClima-LAC Project contribution

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KEY WORDS: water resources, coastal aquifers, coastal management, climate change

ABSTRACT

The coastal areas of Latin America and the Caribbean, have been poorly integrated into socio-economic development. Many of them have been impacted by waste and polluted water, altering ecosystems and impacting human populations. Likewise, in the last decades the effects of climate change are more directly observed in these areas, highlighting the deterioration of water resources either by the marine intrusion or by the increase of extreme events that contrasts with the poor coastal territorial planning and with the demographic increase.

Within the framework of the Regional Program WATERCLIMA-LAC in the context of Climate Change in the Americas Latin America and the Caribbean, is being developed the project Watershed and Coastal zones management, financed by the European Union through the EUROPEAID program. Four pilot areas of the region were chosen to develop the project. These areas are: La Paz (Baja California, Mexico), Basin of the Bajo Lempa (El Salvador), coastal area of Aquin (Haiti) and Mar del Plata (Argentina). The overall objective of the Project is to contribute to improve coastal zone management increasing resilience of Latin America and the Caribbean countries to the impacts to climate change promoting collaboration among regions, and coordination in order to carried out co-management models adapted to the effects of climate change with the purpose of contributing to an efficient, inclusive and sustainable economic growth.

The coastal aquifers of each coastal area are studied focusing into two main different objectives. Groundwater flow models to apply on aquifer management have developed for the cities of Mar del Plata (Argentina) and La Paz (BC Mexico) in order to prevent seawater intrusion and evaluating the situation under the Emissions Scenarios RCP4.5 and RCP8.5. The less populated areas of the Bajo Lempa Aquifer (El Salvador) and Bajo Aquin (Haití) are being object of water quality and pesticides pollution studies, evaluating the impact of the land use changes.

Code of abstract: T7.1.1
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Development of a methodology to identify groundwater dependent ecosystems in Portugal for the implementation of the European Water Framework Directive.

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KEY WORDS - GWDE, WFD, Portugal, hydrogeological criteria, ecologic criteria

ABSTRACT
The European Water Policy has undergone a thorough restructuring process in the last 17 years and the Water Framework Directive adopted in 2000 set the objectives for water protection for the future. In terms of groundwater protection it comprises a prohibition on direct discharges to groundwater and a requirement to monitor both quantity and quality of groundwater bodies so as to guarantee sustainability of groundwater water resources and to detect changes in chemical composition ensuring minimum impact on surface water bodies and on associated groundwater dependent ecosystems (GWDE). For the first phase of the River Basin Management Plans (RBMP) Portugal was missing a unique methodology that could identify GWDE for all the country due to the complexity of the subject and ended up with a long list of potential GWDE of different scales, sizes and degrees of dependence that was almost impossible to manage from the environmental and integrated point of view. The present paper summarizes the methodology developed to identify GWDE in Portugal for the implementation of the European Water Framework Directive and that it has been used for the second phase of the River Basin Management Plans (2016-2021). It considers all the sites from the Natura 2000 and Ramsar networks and sets both hydrological and ecological criteria. The hydrological criteria include information on the topography, climatology, hydrogeology, hydrography and soil and were normalized according to a scale indicative of the probability of interaction with groundwater (3 Very probable; 2 Probable; 1 Not Probable). The ecological criteria included the presence of stygofauna as a key indicator or that of fauna or flora indicative of dependence on groundwater and the data were also normalized. All the set of hydrological and ecological criteria and corresponding normalization values were integrated in a GIS database to calculate the probability of occurrence of a GWDE in any part of the territory and the results indicated different areas and the corresponding degree of dependence on groundwater. The results and the final list of GWEDE for Portugal was validated by APA at regional level and implemented by APA at national scale.

Code of abstract: T7.1.2
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Landscape-Level Methods to Improve Springs Ecosystems Stewardship

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KEY WORDS - springs, inventory, assessment, conservation

ABSTRACT
Places where groundwater discharges at or near the earth's surface are springs. Springs ecosystems support a wide diversity of species and cultures across all landscapes. At least thirteen spheres of discharge have been proposed to classify springs ecosystems. Comprehensive inventory and assessment techniques have been developed and used to describe 1,000s of springs ecosystems across Western North America. Springs support the headwaters of most perennial streams, but the location and identification of springs continues to be limited by the adoption of a universal classification system and database by hydrogeologists. Less than 10 % of the springs on most landscapes have been identified and even fewer have been comprehensively inventoried and assessed. Springs support some of the most productive, biologically, and socio-economically important and threatened ecosystems on the earth. Although springs occupy far less than one % of the land area, inventories of springs across landscapes indicate that up to 25 % of all plant species are supported at springs. Comprehensive inventory and assessment data are accessible on the secure, cloud-sourced Springs Online database of the Springs Stewardship Institute. Inventory and assessment techniques have been adapted and adopted by many land and resource management organizations, including many indigenous nations. Techniques developed to assess the condition and risks of springs ecosystems can be used to prioritize stewardship action across landscapes. Stewardship prioritization is an essential component of successful landscape conservation design planning, especially when resources for stewardship are limited. When successfully implemented, landscape conservation planning can assist with sustaining the important ecosystem services that springs support.

Code of abstract: T7.1.3
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Large-scale pressures on the chemical status of European groundwater bodies

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KEY WORDS: WFD, groundwater bodies, Water Information System for Europe (WISE), chemical status, multi-pressures

ABSTRACT
Groundwaters are impacted by various pressures leading to either depletion of groundwater quantity or/and quality, including groundwater dependent ecosystems. We analysed groundwater status and pressures relevant for groundwater bodes using available data at European scale reported by European countries (WISE-WFD and WISE-SoE datasets managed by the EEA). We analyse spatial extent of ground waters in poor status and the extent of a single pressure, such is pollution from point sources, urbanization and agriculture and pressure combinations causing failure of good groundwater status. We also analyse relationship between groundwater bodies status and protected aquatic (river and lakes) and their ecological status. The analysis of pressure and status shows that prevailing stressor causing failure of good groundwater status is pollution. Pollution in combination with groundwater abstraction appears to be most common pressure combination in Europe. The most common type of groundwater pollutants are agrochemicals (nutrients and pesticides) affecting whole Europe and especially agricultural areas. Most surface water bodies that fail to reach good ecological status are lying on groundwater bodies that fail to reach good chemical status. The results show that in Europe there is a significant link between ecological status of surface water and groundwater chemical status. This fact demonstrates the need for integrated water management and the establishment of common measures to improve status of groundwater bodies.

Code of abstract: T7.1.4
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Hydrogeological and hydrochemical characteristics of volcanic environments supporting groundwater dependent extremophile communities in chilean Central Andes (22°50'-26°05'S)

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KEY WORDS - hydrochemistry, volcanism, fractured rocks, salt flats, extremophiles

ABSTRACT
Between 2014 and 2015 samples of waters and salts were taken in 19 salt flats and lagoons located in the pre-Altiplanic area and the current volcanic arc in the southern zone of the Central Andes (SCVZ), characterized by its extreme aridity and being located more than 3.000 m a.s.l. These bodies of water are recharged almost exclusively through the groundwater circulating through fractures in volcanic rocks and to a lesser extent in volcanic deposits with primary permeability. The analytical results allowed to characterize its superficial geochemistry, while the analysis of available geological information was vital to understand the geological processes occurred in this area and to compare them with the geochemical information. The results of these analyses, although the composition of the waters is mainly sodium chloride with high concentrations of alkali metals, points out to two extreme types: (i) higher calcium concentrations and Ca/SO_4 ratios greater than 1 are coincident with salt flats located in the pre-Altiplanic area or at the west of the current volcanic arc and related to regional reverse faults that affect Cenozoic rocks, without active volcanism in their basins, (ii) higher SO_4 concentrations, Ca/SO_4 ratios lower than 1 and reaching higher concentrations of F-B-As are associated with salt flats and lagoons related to volcanic structures, like caldera rims, with active volcanism in their watersheds. These two types could respond to the influence, in an early stage, of thermal waters rich in CO_2 in the case of type (i) and acid gases in the case of type (ii). Also, it is possible to observe that Ca richer surface water bodies tend to present a greater development of microbial mats and gypsum domes, which constitutes an opportunity to study and compare extremophile communities associated with similar climatic environments but with different geochemical characteristics.

Code of abstract: T7.1.5
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Effects of pH and organic matter content on the sorption behaviors of sulfamethoxazole in two different vadose soils

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KEY WORDS - sulfamethoxazole, sorption, vadose zone, soil, antibiotics

ABSTRACT
Sulfamethoxazole belonging to sulfonamide class of antibiotics is a widely used veterinary medicine that has high potential to enter the vadose zone and groundwater environment, especially the soil compartment by the application of manure on agricultural land and grass land or by the deposition of dung pats on pasture. Once it reaches the vadose zone, it may enter into surface and ground water.
Natural silt loam and sandy loam in the vadose zone, which is widely distributed in China, is regarded as the natural barrier of preventing and controlling contaminant transportation. The interception capacity of natural silt loam and sandy loam to Sulfamethoxazole is really to be expected. Ascertaining sorption characteristics is the key to evaluate and control potential pollution of Sulfamethoxazole to groundwater.
We performed this study to investigate the influences of soil pH and soil organic matter content on the sorption behaviors of sulfamethoxazole in two different vadose soil types (silt loam and sandy loam) in northern China. We evaluated both the Langmuir and Freundlich sorption isotherms and found that the Freundlich sorption isotherm fit the data better than did the Langmuir sorption isotherm because the coefficient of Freundlich sorption isotherm (> 0.8) was considerably greater than those of the Langmuir sorption isotherm. The sorption capacities of sulfamethoxazole increased with decreasing soil pH and increasing soil organic matter content. The sorption capacities of the sulfamethoxazole in silt loam soil were greater than those in sandy loam soil. Furthermore, our results indicated that sulfathiazole was highly mobile in soils and could therefore be rapidly transported to field drains and ultimately entered surface waters. Together, our results indicated that the sorption of sulfamethoxazole by soil was influenced by environmental factors such as soil pH, soil organic matter content.

Code of abstract: T7.1.6
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Metagenomic Approach for the Prediction of Composition and Connectivity between Water Sources

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KEY WORDS - microbial community, metagenomics, groundwater, water source

ABSTRACT

Groundwater-surface water connectivity refers to the direction and magnitude of flow between water resources located above and below ground. Diverse factors such as topography, geology and climate can change the direction and magnitude of these flows which led to the increasing of complexity and difficulty to assessing groundwater-surface water interactions. Understanding the extent of groundwater-surface water connectivity is crucial for the sustainable management of the overall water resource. A range of tools are available to assess the level of connectivity and understand the processes which control the movement of water from surface to sub-surface storages. In this study, we evaluate the metagenomics approach for the prediction of composition and connectivity between water sources in study area. As assessed by tagged Illumina sequencing of the 16S rRNA gene, community composition and structure were clearly distinguished between different water sources such as groundwater, mine discharge water, stream water, and wetland. Interestingly, microbial structures of groundwater also vary in depth and each depth shows connectivity between stream water, wetland, and mine discharge water. These results may suggest the new approach for prediction of water connectivity between water sources based on microbial ecology.

Code of abstract: T7.1.7
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Methodological development for mapping of groundwater dependent ecosystems. Example from Switzerland

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KEY WORDS Groundwater-dependent ecosystems, Geospatial data, Switzerland, GIS, Mapping

ABSTRACT

Environmental legislation (e.g., European Framework Directives on water, on habitats, daughter directive on groundwater) today commits water resource managers to manage hydrosystems in an integrated manner. This implies considering groundwater and surface water not only as exploitable resources characterized by quantitative and qualitative parameters, but also as elements of the landscape characterized by processes (e.g., recharge, circulation, water-rock interactions, bio-geochemical processes) that are of ecological (natural habitats) and socio-environmental (amenity, remediation, sustainable resource) interests that should be ensured. This is peculiarly the case for Groundwater-Dependent Ecosystems (GDE) whose actual and potential locations need to be evaluated in order to implement their sustainable management.

In this context, this work presents a methodology for potential GDE identification. The method is based on 1) conceptual descriptions of the various GDE habitats, i.e. aquifers, hyporheic zones, alluvial forests, springs, marshes and 2) their implementations, through combination of geodata about geology, soil, climatology, topography and hydrology in geographical information systems.

In order to control the applicability and reliability of this method, this approach is exemplified and discussed in Switzerland at local and national scales. This study highlights that this methodology presents the advantage to be easily implemented and that the lack of information can be often buffered by the use of proxy data. The interest of such approach is that, although it can be more detailed by using high resolution and remote data, it makes it possible to be used in many areas featuring various biogeographical contexts and where geospatial data are limited to basic information.

Code of abstract: T7.1.8
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.1. Methods for characterisation of groundwater dependent ecosystems

Stress-induced over NATURA 2000 sites in Romania, based on the land use and the state of groundwater and terrestrial ecosystems

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KEY WORDS - hydrogeological and environmental criteria, SCI_NATURA 2000, GIS

ABSTRACT

Romania's accession to the European Union significantly contributed to the Natura 2000 network of protected natural areas. The Natura 2000 network in Romania is currently being expanded, while the number of sites and the boundaries of some of them are subject to revision.

The proposed methodology for evaluation of stress-induced includes two criteria: stress intensity ranking and weighting stress intensity based on spatial extension sites.Ranking stress intensity is proposed to be achieved in two stages, using:

- discriminant analysis and factor analysis for type of land use mainly;
- intensity of dependence between ecosystems and groundwater based on two categories of criteria: *hydrogeological criteria* (**HC:** aquifer formations lithology, vadose zone moisture, piezometric level depth and qroundwater quality) and *environmental criteria* (**EC:** the number of characteristic organisms, production function etc.).

The 44 classes of land use (from Corine database) were filtered in three stages: a) the exclusion of non-specific categories for Romania (223-Olive groves, 522-Estuaries etc); b) removing classes with reduced spatial extension (213 - Rice fields; 332 - Bare rocks etc); c) removing classes with reduced weight for each site.

Analysis of intensity of dependence contains two algorithms: one for identifying potential ecosystems dependent on groundwater and one for estimating the intensity of interdependence on three levels: *high dependence* (**A: 100%**), *medium dependence* (**B: 50%**) and *nule dependence* (**C: 0%**).

The proposed methodology is going to be applied on383 protected areas of type SACs which has a total surface of $4.1x10^6$ hectares (17.41% of the Romanian's territory).The proposed analysis are based GIS techniques and database consist on information from public monitoring systems of groundwater, SCIs-Natura2000 and habitats.

Code of abstract: T7.2.1
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Comprehensive hydrogeological study to reveal groundwater-dependency of the largest lacustrine ecosystem in Central Europe

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KEY WORDS hydraulic data processing, numerical simulation, hydrochemistry, regional discharge

ABSTRACT
Groundwater-dependent ecosystems (GDEs) are highly influenced by the available amount of groundwater, seasonal variation of precipitation and consequent water table fluctuation and also the anthropogenic activities. They can be regarded as natural surface manifestations of the flowing groundwater. The preservation of environment and biodiversity of these GDEs is an important issue worldwide. Water management policy could not be worked out in absence of comprehensive hydrogeological models. The concept of gravity-driven regional groundwater flow and related approaches could aid the understanding of flow pattern and interpretation of environmental processes and conditions.
Hydraulic position of the Lake Balaton, the largest lacustrine ecosystem in Central Europe, has not been previously studied in the context of the surrounding groundwater flow systems, however, it is important to reveal the potential effect of planned groundwater withdrawal in the region. Therefore, we proposed a systematic study to disclose the hydrogeological processes operating on different space and time scale. First of all, hydraulic database of wells was compiled, culled and filtered. Applying the hydraulic data processing, i.e. tomographic potential maps, p(z) profiles and hydraulic sections, we can have a general idea about the subsurface hydraulic processes: the recharge, through–flow (it was neglected previously) and discharge areas can be outlined, direction and scale of groundwater flow can be assessed. Land and water seismic measurements and geologic sections were the basis of a regional-scale numerical simulation. The results were also validated by temperature and water chemistry of springs.
The preliminary outcomes of this study revealed 1) the regional hydraulic situation and position of the Lake Balaton, 2) the interaction and connection of surface and groundwater, 3) the effect of asymmetric basin geometry on flow pattern, 4) the generally low geothermal potential of the region and 5) the influence of groundwater on lake water balance, chemical composition and ecosystem.

Code of abstract: T7.2.2
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Field measurements of the direction and magnitude of groundwater and surface water exchange in the hyporheic zone

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KEY WORDS hyporheic zone, gradientmeter, filtrometer

ABSTRACT
The examination of hyporheic zone, i.e. the zone alongside the streambed where mixing of groundwater and surface water take place, is crucial in order to determine the conditions of filtration and contaminant transport between surface water and groundwater.
The hydraulic parameters of the hyporheic zone can be investigated using a gradientmeter and a filtrometer (both devices briefly described during the presentation). The gradientmeter was designed and constructed to establish the direction of water flow, whereas the filtrometer allows to determine the intensity of this flow. After performing measurements with both devices, it is possible to calculate the hydraulic conductivity of the hyporheic zone.
The gradientmeter and filtrometer were tested in field conditions. Observations of groundwater seepage into surface waters were performed on the Parseta River (Northern Poland). The results were verified by analyzing the increase of volumetric water flow in the analyzed section of the Parseta. Observations of seepage loss into the saturated zone were performed at the "Debina" infiltration water intake in Poznan (Central Poland). The results were verified by analyzing the rate at which the water level decreases in the infiltration pond after pumping water into the pond was ceased. The field research proved that the discussed measuring devices are useful when examining the properties of the hyporheic zone responsible for contaminant transport.
The field research proved that the application of the gradientmeter and filtrometer expands the capability of examining the hyporheic zone. Furthermore, the discussed devices are useful in cases of water contamination, since they measure parameters of the hyporheic zone responsible for contaminant transport.

Acknowledgements
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2. NCN 2015/17/8/ST10/01833 entitled: "Conditions of the daily fluctuations in the levels of water in rivers and springs taking into account the influence of hyporheic zone".

Code of abstract: T7.2.3
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Biogeochemical connectivity in aquifer-river continuum – use of *in situ* ^{222}Rn and PCO_2 measurements in the study of CO_2 outgassing induced by groundwater discharges in river

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KEY WORDS
aquifer-river continuum ; radon ; CO2 ; in situ measurements

ABSTRACT

In a carbon global budget, rivers are generally considered as passive vectors convoying terrestrial carbon to the ocean. This fluvial transport, with a flux estimated at 0,9 Gt.C.an^{-1}, represents the main link between continents and oceans. However, dissolved inorganic carbon (DIC) is convoyed in a dynamic open fluvial system controlled by catchment lithology, soils type, and aquatic metabolism, exposed to hydrometerological forcing and affected by CO_2 exchanges to the atmosphere. So, rivers do not only transport carbon to the ocean, they encompass biogeochemical reactions that promote transformation along the fluvial journey. Carbon, for example, can be emitted from sediments to the atmosphere as well from groundwater sources. Exchanges from groundwater sources appear to be highly significant in first order rivers. These sporadic and heterogeneous inputs form intermittent biogeochemical "hotspots" produce "hotmoments" where CO_2 could rapidly degas to the atmosphere. Nevertheless, localizing and precisely quantifying CO_2 outgassing associated with groundwater flow to rivers is very difficult. We propose a methodology that combines radon-222 to trace groundwater discharges into rivers with in-situ analyses of CO_2 partial pressure (PCO_2) to estimate CO_2 emission from rivers in relation to groundwater-river connectivity. This methodology is based on discrete water samplings systematically realized along the river, and in piezometers localized in the catchment. It was applied on the Matane river (QC, Canada) to estimate a first budget in term of groundwater discharges and carbon emissions. Data collected between spring 2015 and summer 2017 present higher radon activity and higher PCO_2 in particular points of the studied site. These results suggest a link between localization of groundwater discharges and morphological characteristics of the meandering river. Locally, the identification of groundwater exfiltration sites in the river combined with the quantification of hydrological and nutritional fluxes will promote a better understanding of aquatic ecosystem behavior in rivers. Furthermore, at a larger scale, this study aims at contributing to the improvement of carbon global budget understanding and so in the improvement of models used in global warming predictions.

Code of abstract: T7.2.4
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Groundwater-stream connectivity and the fate of agricultural nutrients in coastal watersheds

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KEY WORDS - groundwater, agriculture, nutrients, water quality, coastal waters

ABSTRACT
Elevated concentrations of nitrate (NO_3^-) in groundwater are common in the Atlantic Coastal Plain, USA, due to use of chemical fertilizers in agriculture. Infiltration through the unsaturated zone carries NO_3^- to the underlying unconsolidated, unconfined, sandy aquifer. Groundwater subsequently discharges to gaining streams that deliver a significant nitrogen (N) load to coastal waters. Biogeochemical reactions occur to varied extents in the streambed sediments through which groundwater connects to streams. Based on periodic measurements of stream discharge and solute concentration at multiple streams, regional annual NO_3^- flux was approximated. In comparison to rates of fertilizer application, seaside lagoons receive only ~23% of the applied N, a value lower than can be accounted for by plant uptake. In one low-relief stream in Virginia, denitrification in streambed sediments removed 70-90% of the NO_3^- present in groundwater. A multi-year study of N flux from 16 separate watersheds revealed a range of magnitudes of NO_3^- reduction. We investigated hydrogeological and geochemical factors that may determine the potential for denitrification to reduce the delivery of nutrients to eutrophic coastal waters.
Four streams with an annual N flux of 3-7 kg NO_3^- per ha were studied to elucidate connectivity of groundwater and streams. Hydraulic head measured in multi-level piezometers installed in the stream channel revealed groundwater head exceeding stream elevation. Streambed sediment cores were collected, and subcores were evaluated for hydraulic conductivity, organic matter (OM) content, and porewater NO_3^-. Although draining a uniform geology, sediment varied physically and chemically. Hydraulic conductivity had a strong inverse relationship to OM content, resulting in the longest residence time of groundwater being associated with OM-rich intervals that controlled upward flow rates. NO_3^- concentration had a weak inverse relationship to OM, but concentration in the porewater was low overall. The stream with the most conductive sediments had the highest NO_3^- concentrations. For three streams, NO_3^- exceeded levels in porewater suggesting that upstream surface-water conditions were an unquantified and influential factor in determining stream NO_3^- concentration even in strongly gaining streams.

Code of abstract: T7.2.5
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Hydro-chemical and geophysical techniques investigating dynamics and sources of DIC within a catchment possessing a Groundwater Fed Lake (Lough Gur, Ireland)

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KEY WORDS - Lacustrine groundwater discharge, Multi-Aquifer, Isotopes, Hydrochemistry, DIC, Nutrients

ABSTRACT

Lake groundwater discharge (LGD) is often disregarded in many lake nutrient and eutrophication studies. Notwithstanding, water resource managers internationally and in Ireland now acknowledge the adverse impacts of high nutrient concentrations in lacustrine ecosystems resulting from groundwater discharge. Hence, understanding the temporal and spatial distribution of groundwater dissolved inorganic carbon (DIC) species is important in understanding the nutrient biogeochemistry of groundwater dependent aquatic ecosystems.

Isotope techniques including $\delta^{18}O_{H2O}$ and $\delta^{2}H_{H2O}$, in conjunction with hydro-chemical species were used to constrain sources of water to the lake. In addition, other isotope tracers such as $\delta^{13}C_{DIC}$ and $\delta^{15}N_{NO3-}$ and $\delta^{18}O_{NO3-}$ along with catchment well-lake gradients, vertical lake-aquifer hydraulic gradients and geophysical surveys were used to trace groundwater seepage and biogeochemical processes impacting lake hydrochemistry and transformation of nutrients, while attempting to constrain recharge patterns and processes connected to the groundwater fed lake.

Hydrographs of wells and lake water levels showed a strong GW-SW connection in the catchment. Rn surveys which identified areas within the lake possessing strong Rn anomaly temporal dynamics, suggesting groundwater discharge at these locations within the lake. ERT survey results measured lateral and vertical variations of subsurface electrical resistivity and have partially revealed the orientation and extent of a subsurface conduit system at Lough Gur. $\delta^{15}N_{NO3-}$ and $\delta^{18}O_{NO3-}$ suggested denitrification was a dominant process with seasonal variation with surface and groundwaters and in-lake piezometers at groundwater discharge locations. Seasonal DIC dynamics were identified with a negative correlation between $\delta^{13}C_{DIC}$ (‰) and DOC (mg l^{-1}) indicating dissolution of carbonates by carbonic acid in groundwater wells. In contrast, a positive correlation between $\delta^{13}C_{DIC}$ (‰) and DOC (mg l^{-1}) implies that oxidation of organic matter was a major source of DIC within the lake. Due to different sources of DIC and geological materials having different isotopic compositions, stable carbon isotopes of DIC are a useful tool to trace the source of DIC and the evolution of groundwater.

Code of abstract: T7.2.6
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Identifying and modelling sustainable groundwater inflows into the Verlorenvlei coastal estuarine system in South Africa

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KEY WORDS Isotopes, Verlorenvlei, Climate Change, Recharge, Sustainability

ABSTRACT
The Verlorenvlei estuarine system is one of only two estuarine systems in South Africa. Whilst being important ecologically is also a critical agricultural region, supporting a significant proportion of the South African potato crop as well as a number of other diverse crops. The vlei itself is fed by the Verlorenvlei River which is thought to be fed by surface water inflows and baseflow throughout the year along several tributaries, namely the Krom Antonies, Hol, Berg Vallei and Kruismans. Each of these tributaries has a distinct hydrochemical character defined by cation and anion concentrations, as well as O, H and Sr isotopes. Simulated discharge from each tributary suggests that all tributaries contribute to the chemistry of the Verlorenvlei River. The Krom Antonies which has the freshest water has the highest discharge at around 50% of surface water inflows, whilst the Hol with the highest EC values contributes around 35% of surface water inflows. In spite of this, the surface water hydrochemistry in the Verlorenvlei River, is remarkedly fresh and very similar in character to the surface water of the Krom Antonies. Sr isotopes in each of the tributaries are clearly distinct and support mixing of different components of each tributary above the confluence. However, below the confluence, they drop significantly and indicate mixing with another as yet unidentified Sr-source. This source was thought to be baseflow from the deeper groundwater system, but the Sr isotope composition of deeper groundwater indicates that it is not the contributing component. Recent years have seen dramatic reductions in precipitation and pumping for agricultural purposes is at or just exceeding the long term sustainable yield of the aquifer system. Identification of this unknown component has therefore become a priority for groundwater management in the area as it is unclear how vulnerable this component will be to climate change and hence what impact climate change will have on the vlei.

Code of abstract: T7.2.7
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Characterization of dissolved organic matter in groundwater and surface water in artificial recharge demonstration site using fluorescence 3D EEM-PARAFAC

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KEY WORDS Dissolved organic matter, Artificial Recharge, Groundwater, Fluorescence, 3D EEM-PARAFAC

ABSTRACT
Dissolved organic matter (DOM) has been used to figure out the quality and reaction processes of groundwater and surface water in aquatic systems. DOM fluorescence properties can be useful tolls to identify the types and the origin of DOM, the mechanism of biochemical reactions, and the monitoring of pollutants reduction on many studies. To characterize the hydrogeochemistry and dissolved organic matter (DOM) of aquatic systems, the field survey and lab experiments were performed in August and November of 2015. The test site, Sangju, was a typical rural area with aquatic system of small pond, reservoir, streams, and groundwater used as drinking water source. In this study, we have characterized the fluorescent dissolved organic matter (DOM) in the surface water (IK-A ~IK-D) and groundwater (IK-E~IK-H) samples in KIGAM managed artificial recharge demonstration site in Sangju city, Korea. The hydrogeochemical analysis on the collected water sample showed [Ca-HCO_3] types except for groundwaters which classified as [Ca-(HCO_3+SO_4)] type. To identify the features of the chemical structure, DOC, UV absorbance, and specific ultraviolet absorbance were also performed. As a result, surface water DOM contained more aromatic organic carbon compounds than groundwater. The humification index (HIX) results show that the humification degree of surface water is larger than that of groundwater. However, fluorescence index (FI) and biological index (BIX) results show that the origin is autochthonous. To provide more accurate analysis, fluorescence 3D-excitation emission mapping (3D-EEM), synchronous fluorescence spectrum and parallel factor analysis are additionally performed. The results show that the DOM of the surface water is mainly composed of more aquatic humic-like autochthonous matters than terrestrial humic-like allochthonous matters. Also, the DOM of the groundwater is mainly composed of tryptophan and tyrosine which are protein-like matters. The fate of major DOM components at pumping well (SPW-1) were also monitored to assess the interaction between aquifer and near wetland (IK-A) during the pumping test. Two humic-like components (C1, humic-acid and C2, fulvic-acid) and two protein-like components (C3, tyrosine and C4, tryptophan) were identified in the groundwater and surface water. The components C1 and C2 were detected showing significantly high intensity in wetland (IK-A), reservoir (IK-B) and brook (IK-C) samples, while very weak fraction in the groundwater-like samples (IK-D ~IK-H). During pumping test, the fluorescence intensity of humic-acid components slightly increased while tryptophan component significantly decreased in SPW-1 which is well correlated with the trend of biological index (BIX) values. The fluorescent pattern at SPW-1 had been similar with that of near wetland over time indicating possibility of inflow from wetland. This study provides the potential application of EEM-PARAFAC analysis to understand the characteristics of DOM in the groundwater and assess the aquifer connectivity with near surface water.

Code of abstract: T7.2.8
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Conditions of recharge and discharge of groundwater in a small basin with a complex geological structure - Lutynka River basin (SE Poland)

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KEYWORDS - water level fluctuation, recharge, tectonic conditions, dry valley, surface runoff

ABSTRACT

The aim of the investigations was to identify the conditions of infiltration and flow of precipitation and runoff water in a dry valley bottom. The valley is situated in Western Roztocze (SE Poland). It formed in Cretaceous-Neogene bedrock and was covered by silt-sandy Quaternary sediments.
In the bottom of the valley, measurements of the permeability of subsurface formations were performed with various methods, which indicated that the permeability in this fragment of the valley changed relative to the morphological position. The highest permeability values were noted for the lowest fragments of the valley slopes, i.e. in areas with sandy formations exposed on the surface. Intermediate values were characteristic for the valley bottom and the lowest values were found for plateaus covered by loess and clay formations. The valley bottom was characterised by a variable level of permeability. The highest values were noted at the slope-bottom interface and in the central part of the valley. In turn, lower values were found for the valley bottom zones adjoining directly to the slopes.
The study also involved determination of the reaction time of the piezometric surface of the main aquifer and the perched aquifer in wells located in different geological and morphological conditions. It was found that the groundwater table of the main aquifer was directly associated with the perched aquifer present in the valley.
The studies demonstrated partial loss of runoff waters in the Lutynka valley, which indicates its privileged position in the process of accumulation and infiltration of precipitation/melt water and proves its important role in recharging the aquifers.
The results also showed that the Lutynka paleovalley formed in Cretaceous rocks is the main zone that drains underground waters of the main aquifer. Probably higher values of the groundwater flow are found on the left side of the valley, which is suggested by the lowest groundwater locations.

Code of abstract: T7.2.9
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Groundwater-socio dynamic of a coastal system: A paradigm key for the resilience of a lagoon ecosystem

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KEY WORDS Groundwater dependent ecosystem, nitrate sources, groundwater dating, resilience

ABSTRACT

The co-evolution, along several decennia, of the groundwater quality and the anthropogenic activities has to be considered as a first point for a global thinking about the sustainable management of the territories. A transversal strategy is important to adopt an efficient human-groundwater-ecosystem management in particular for the coastal Mediterranean areas. The Biguglia lagoon catchment is an interesting example which is the place of many land-use conflicts with important environmental issue as the lagoon is considered a Natural Reserve since 1990.
The Biguglia lagoon catchment is together a major ecological hydrosystem of Corsica Island, a remarkable zone with a fast urbanization in the last 30 years and an area where agricultural practices have been strongly modified since 50 years (vineyards were replaced by sheep and poultry farming). The role of the groundwater is strategic: the aquifer is hydraulically connected to the lagoon and groundwater are also used as a water supply resource for the Bastia city (60 000 inhabitants).
The aim of the study is to define the origin and to date the anthropogenic activities footprints on the groundwater with a combined socio-hydrogeological approach. A resilience analyse was led considering the groundwater as a main node of the socio-ecologic system which is the lagoon. In addition, in April 2016, the nitrate sources, major ions and traces elements were measured in 20 points (15 groundwater and 5 surface waters) and the age of the groundwater were evaluated with tritium and atmospheric anthropogenic gases (CFCs and SF6) for 5 selected groundwater points.
The noticeable nitrate concentrations (> 30 mg/L) indicate an origin in total accordance with the agricultural practices (past and current) and the location of the sewage network around the lagoon.
The combined approach allows proposing a global dynamic system, where the link between the dynamic social influences are clearly expressed in the groundwater quality. Taking into account the groundwater resilience factors is one of the key issues for the global management of Mediterranean lagoons.

Code of abstract: T7.2.10
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Multivariate geostatistical techniques for redox zonation assessment in a tropical alluvial aquifer

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KEY WORDS multivariate geostatistics, Factorial cokriging, redox processes, eutrophication, tropical area

ABSTRACT
When high concentrations of Mn and Fe are detected in groundwater, the redox processes are likely occurring in the aquifer. They are due to organic matter oxidation, which can be naturally present in the solid matrix or released in the aquifer by anthropic activities. Thus, the definition of redox zonation within an aquifer can be an effective tool for the conceptual model refinement in remediation strategies planning.
In developing countries, either the incorrect management of wastewaters or the land use distribution can affect the environmental quality of surface-water, creating eutrophication conditions in the main streams. In hydrogeological contexts where a multilayer alluvial aquifer is connected with surface-water, also the groundwater quality degrades and redox processes can occur. This issue complicates the groundwater study, its exploitation for drinking purpose and its management.
The objectives of the study are to investigate the effect of the surface-water/groundwater interactions of San Pedro Sula alluvial aquifer, located in north-western Honduras, on the redox zonation, performing a partition of the aquifer in homogeneous areas.
The datasets available refer to 2 monitoring rounds performed in 2002 (wet and in the dry season) consisting of 94 groundwater samplings. In each sample, chemico-physical parameters (pH, EC, Temp, Turb) and analytes (Na, K, Ca, Mg, HCO_3, Cl, SO_4, NO_3, NH_4, PO_4, Fe, Mn) have been assessed.
To assess hydrogeochemical spatial relationships among the variables involved in the redox processes, a multivariate geostatistical approach was performed, called Factorial cokriging, consisting in three main steps: 1) Gaussian anamorphosis to transform raw variables into Gaussian transformed variables; 2) fitting a Linear Model of Coregionalization, including the variogram models of both direct and cross-variograms; 3) extraction and interpolation of the sets of scale-dependent regionalized factors.
The first results show a strong relation of Mn concentration with redox processes, which may be ascribed to the organic matter transfer from heavy polluted surface-water to the aquifer. For Fe, its relation to turbidity can be due to a fine colloidal phase developed when different groundwaters, characterized by distinct redox conditions, mix up in the wells.

Code of abstract: T7.2.11
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Spatial and temporal changes in groundwater dependence of headwater streams in boreal region

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KEY WORDS -groundwater-dependent ecosystems, streams, stable isotopes of water, environmental tracers, thermal imaging

ABSTRACT
Headwater streams have been recognized for their strong control on downstream hydrological and geochemical processes and ecological functions. Groundwater maintains the base flow of these ecosystems and therefore any changes in groundwater discharge to headwater streams can also have an impact downstream. Spatial and temporal behavior of headwater streams was studied in boreal region in order to assess the groundwater dependence of these ecosystems. The studied streams, two disturbed and one pristine, were continuously measured for discharge, electrical conductivity and temperature during 2013-2014. Loggers were installed for different parts of the streams to study the spatial variations of these variables along the streams. In addition to continuous monitoring, streams were sampled for stable isotopes of water, nutrients, water quality parameters, silica, major cations and anions and alkalinity from several different points quarterly during years 2013 and 2014. Thermal imaging of the streams was conducted to pinpoint groundwater seepages along the streams. The results indicate that all the streams are highly groundwater-dependent at times, but for example during rainy autumn and snow melt seasons, the surface water contributions increase especially downstream. Principal component analysis showed that the water quality of all the streams deviated from each other even though two of the streams discharged from the same aquifer and had adjacent catchment areas. This study shows that an approach combining continuous measurements and discrete sampling from several location along the streams can be efficient to capture the complex spatial and temporal behavior of headwater streams.

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Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.2.Groundwater and associated aquatic ecosystems

Assessment of groundwater status in areas with groundwater-associated aquatic and terrestrial ecosystems in Croatia

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KEY WORDS - WFD, groundwater associated aquatic ecosystems, groundwater dependent terrestrial ecosystems, groundwater dependent aquatic ecosystems, Croatia

ABSTRACT
According to the EU Water Framework Directive, groundwater has a good status if anthropogenic changes do not significantly endanger surface waters connected to them and do not significantly harm terrestrial ecosystems dependent on them.
A status assessment of groundwater bodies (GWB) from the standpoint of groundwater-associated aquatic ecosystems (GWAAE) and groundwater-dependent terrestrial ecosystems (GDTE) was made for Croatian Waters (Hrvatske vode) and needs of River Basin Management Plan for the period 2016 – 2021. GWAAE and GWDTE were isolated, and a methodology for a status assessment of associated groundwater was defined. The methodology for risk assessment indicates failure to achieve a good status if the groundwater status is not satisfactory or a risk of failure to achieve the goal of "preventing status deterioration" if the groundwater status is satisfactory, but there is large pressure on the groundwater. The interconnection of groundwater with surface waters is characteristic of almost all GWBs in Croatia. In karst areas, groundwater-dependent aquatic ecosystems (springs and speleological objects) predominate, while in the Pannonian part of Croatia, there are groundwater-dependent terrestrial ecosystems. The groundwater status and risk assessment were analysed from two standpoints – the quantity and quality of groundwater. On the basis of the proposed methodologies in all GWBs, the status was defined as good. One GWB was marked as being at risk. The reliability of these assessments is often low because of low data availability. A proposition for research monitoring was developed, with the purpose of more thoroughly defining the groundwater status with dependent ecosystems in the future.

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Topic: T7. Groundwater and Dependent Ecosystems
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Potential impacts of drought to stream baseflow and dependent ecosystems

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KEY WORDS ecological drought, baseflow, groundwater discharges, benthic invertebrate, dependent ecosystem

ABSTRACT
Long-period and pervasive deficit in water supplies can alter some processes of natural ecosystems, causing potential threats to ecosystem function. Such environmental consequences of droughts draw attention to 'ecological drought', that is defined as 'a prolonged and widespread deficit in naturally available water supplies that create multiple stresses across ecosystems' by The Science for Nature and People (SNAP) Ecological Drought Working Group of the US. This work is a preliminary study to analyze the effect of drought on stream baseflow by modeling groundwater flow interacting with streams in watershed scales, then examine how it relates to biodiversity in stream ecosystem. Baseflow is calculated to contribute approximately 90% of Nakdong river and even more in dry season(December, January). A long-term deficit in rainfall results in lowering groundwater levels and reducing baseflow. Biomass analysis shows that benthic invertebrates mass is influenced by the amount of baseflow, which comprises mainly groundwater discharge to a stream: Less baseflow(groundwater discharges), less benthic invertebrates. It is noted that biomass analysis presents a dramatic loss of benthic invertebrates mass with a long-term rainfall deficit. It is also noticeable that temperature of benthic zones of a stream is highly related to benthic invertebrates' life. The temperature of benthic zones in dry seasons is calculated to be significantly affected by groundwater discharges to stream. It concludes that groundwater discharges to a stream as baseflow is a key to control benthic invertebrates in the stream when drought occurs. The results may indicate that one should consider quantitative as well as qualitative aspects of environmental water requirement for stream ecosystems, because stream ecosystems are highly dependent on groundwater discharges during droughts.

Code of abstract: T7.3.1
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Groundwater-surface water interaction in peatlands: modes of interaction at different scales

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KEY WORDS – hydrological processes, conceptual models, groundwater-dependent ecosystems, measurement techniques

ABSTRACT

Peat soils are globally important and widespread in the boreal and arctic regions providing various important ecosystem services related to i.e. flood control, recreation, carbon storage and sequestration. They are often connected to groundwater and surface water systems providing base flow and storm water storage, but the hydrogeological processes supporting peatlands are not yet well understood. The traditional conceptual model of bog receiving precipitation and fens receiving also runoff and groundwater flows has recently been challenged and further refined. Here different water holding properties, runoff and groundwater interaction are discussed to get a more comprehensive view of peatland hydrology. We review hydrogeology of pristine and drained peatlands based on 25 years of research experience on the topic from different climatic conditions, peat type, topography and land cover percentage. We present monitoring approaches and conceptual models for peatland hydrology from pore and local scale vertical and horizontal flow processes, to interaction with catchment and aquifer scale hydrology. Exfiltration and infiltration from and to groundwater is discussed in the context of different peatland use from pristine to drained and restored sites.

Code of abstract: T7.3.2
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Long-term impacts and controls of peripheral drainage on the ecohydrology and carbon balance of an intact raised bog

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KEY WORDS Raised bog, carbon, climate change, Ireland

ABSTRACT
Raised bogs are typically considered ombrotrophic wetlands, in that rainfall acts as the dominant control on their hydrological and ecological functioning. However, long-term monitoring of a raised bog in Ireland has demonstrated that these wetlands can display a significant groundwater dependency, with an upward gradient in the underlying groundwater body acting as a supporting condition for the peatland above. When this equilibrium is disturbed, in this case by peripheral drainage impacting the groundwater body, it can have severe and lasting impacts on ecosystem function. In damaged systems, morphological changes due to drainage and consequent peat subsidence occur but the long term effects are rarely recorded or monitored. Detailed ecohydrological monitoring of Clara raised bog over a 25-year period shows continued peat subsidence long after initial drainage. The continual movement of surface catchment boundaries and progressive degradation of critical peat-forming communities has impacted on one key function of the habitat, as a carbon store. An intensive field monitoring programme measured the net ecosystem exchange (NEE) of the habitat and the export of dissolved organic carbon (DOC) from the bog's drainage system, in addition to the rate of CO_2 evasion from the drainage waters. Results indicate that carbon losses in aquatic pathways are as significant as losses incurred via surface emissions. Though this peatland is free of superficial drainage, its overall carbon balance is one of carbon loss due to the impact of peripheral drainage and associated hydrogeological pressures, an underrepresented carbon flux pathway in peatland monitoring and modelling studies. The capacity of degraded peatlands to sequester carbon with active management ensures they are prominent in the debate on the solutions needed to combat the effects of climate change. However, this study demonstrates the difficulty restoring a positive sequestration function following environmental damage where regional groundwater dependencies have been modified.

Code of abstract: T7.3.3
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Studying the dependence of wetlands and related ecosystems on groundwater in different climatic and hydrogeological settings using multiple tools

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KEY WORDS - Groundwater-wetland interactions, natural and non-natural tracers, hydrochemistry, alkalinity, nitrate

ABSTRACT
The only way to preserve wetlands from possible threats from human activities, is through an increased understanding of their functioning and level of dependence on groundwater. As this further depends on the climatic and hydrogeological settings, it is interesting to compare studies from different areas. Here results are presented and compared from a number of studies carried out or still ongoing, employing multiple hydrochemical and hydrological tools, in settings ranging from Mediterranean (South Portugal) and semi-arid Africa (South Kenya) to tropical savannah (Cauca Valley, Colombia), among others. These studies allow us to understand how wetlands and ecosystems interact with groundwater, and to what degree they are threatened by overabstraction and contamination. Many of the wetlands are bordered by intensive agricultural activities that threaten the qualitative and quantitative status of groundwater, and as a result the ecological status of dependent ecosystems. It is shown that the appearance of algal blooms in coastal lagoons can be correlated to the presence of nutrient-loaded groundwater, and that the main nutrient of concern is nitrate, which can therefore be used as a non-natural tracer. This is particularly the case in aerobic environments, where nitrate is extremely stable. On the other hand, dissolved bicarbonate, CO_2 and silica contents are found to be powerful natural tracers of groundwater in all studied wetlands. The first two parameters can easily be obtained in the field by careful in situ measurements of pH and alkalinity. In all studies the use of these hydrochemical tracers, as well as other dissolved ions such chloride, sulphate and ferrous iron, have shown to reveal the spatial as well as the seasonal variation of groundwater dependency of the wetlands and dependent ecosystems. The results are more conclusive when combined with continuous and consistent piezometric measurements in surface and groundwater. Moreover, they aid in the calibration and validation of numerical models built for several of the studied areas. Together these tools serve groundwater management purposes, as they will contribute to optimizing the locations and timings of groundwater pumping and irrigation activities, as well as showing the wetland areas that need to be targeted for remediation and conservation.

Code of abstract: T7.3.4
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

The characteristic of extinction depth of shallow groundwater on the high-latitude region: Case study on the Sanjiang Plain, Northeast China

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KEY WORDS：extinction depth of shallow groundwater (EDSG), high-latitude region, ecosystem sustaining and groundwater resources management, Sanjiang Plain

ABSTRACT
Accurate estimation of extinction depth of shallow groundwater (EDSG) is important for sustainable management of water resources and ecology protection in intensively irrigated region. In this study, the Averyanov' equation method was used to understand the spatial variability of EDSG in the Sanjiang Plain, one of China's largest grain production bases and China's largest inland freshwater wetland region. The study showed a large spatial variation of EDSG in the region, with identifying a range of EDSG between 2.0 m and 14.3 m. Spatially, the sites which were in the northeast had a deeper EDSG, whereby indicate that has higher pumping potential capacity than other sites. Different vegetation also has different EDSG. Using the current shallow groundwater, we identified that 35.3% of the entire Sanjiang Plain have beyond their EDSG ranges. Knowledge of the variation of EDSG range for a certain plant system and the current shallow groundwater condition in the higher latitude region can be a key to the development of preventive actions for large quantity pumping groundwater and protection regional ecosystem.

Code of abstract: T7.3.5
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

The role of groundwater in cork oak woodlands during the dry season

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KEY WORDS Groundwater dependent terrestrial ecosystems; SPEI; Dendrochronology; Mediterranean woodlands; radial stem growth

ABSTRACT

Cork oak forests are characteristic components of Mediterranean landscapes and they cover about 2.2 million ha, almost all of which is in the Mediterranean countries of Portugal, Spain, Morocco, Algeria, Tunisia France and Italy. In 2015, the total world cork exports reached 1,430.8 million euros.

Stem diameter is among the most sensitive characteristics in trees likely to be affected by changing environmental conditions. This is notably illustrated by the cork oak that it is periodically harvested for bark (cork) over its lifetime. So far, little is known about the sensitivity and resilience of cork oak to lowering groundwater levels during one cork production cycle (9–10 years). The aim of this work was to infer the degree and timing of cork tree dependency on groundwater and to assess whether differences in groundwater depth can influence annual cork growth patterns.

Two cases studies with contrasting groundwater levels but, with similar biophysical characteristics were chosen in a state-owned farm. At this farm, stem radial (wood and cork) growth is initiated during March–April, with an intense spring growth flush and continues during the dry summer period. The study areas are located in the unconfined and shallow alluvium aquifer of the Tagus River. The aquifer recharge period mainly occurs during the wet season (between October/November to March/April).

The dendrochronological study on cork rings provided new insights on the cork growth response to groundwater levels. The 6-month SPEI (Standardised Precipitation-Evapotranspiration Index) established two severe drought periods (2005 and 2009) but only the former one resulted in deeper groundwater levels at both study areas. These deeper groundwater levels immediately resulted in narrow cork-rings, being the water table, on average, lower than 3 meters in both sites. Indeed, deeper the groundwater levels in dry period, higher the reduction of the cork growth index. Furthermore, younger and older cork trees had different monthly radial growth behavior during the cork production cycle. Under changing Mediterranean environments, with expected increase in drought events, the decrease of groundwater levels may severely affect cork (and tree) growth and ultimately tree survival.

Code of abstract: T7.3.6
Type of presentation: Oral presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

The relationship between shallow groundwater and vegetation development characteristics—A case study of Manas River Basin in Xinjiang, China

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KEY WORDS：vegetation coverage, shallow groundwater, the characteristic of soil, water content

ABSTRACT

Through the field investigation of vegetation growth and distribute, geomorphology and landscape, soil character and depth of shallow groundwater at Manas river, analyzed the field and laboratory test result include the condition of groundwater embedment, soil component, soluble salt, discussed the relationship between this result and vegetation growth character, summarized the effects that climate condition, environment condition, and shallow groundwater impress on vegetation growth. According to vegetation growth, cover ratio, category and distributing status, the vegetation can be divide to four class from headstream to backward position, include high density、mid-density、sparse grassland and desert, get the conclusion that the groundwater buried depth is the main cause impress on vegetation cover; Then classify the limitation of groundwater level bedding in each type grassland considering the investigate distribution. High density vegetation is mainly locate near river and lake where groundwater lever low than 2.5 meters, 5.0 meters is the critical water level of high density vegetation and desert, and show that soil component, water content, soluble salt content are also the important reason on vegetation growth. Research suggests that the buried depth of ground water is the decisive factor that influences the vegetation coverage. The Manas River Basin is divided into four regions, i.e., the regions with high, medium and low vegetation coverage and the desert region. The boundary line of buried depth to distinguish the four regions is respectively 2.5 m, 4.0 m and 5.0 m. In the area with the buried depth of shallow groundwater lower than 2.5 m, the vegetation coverage is high. These regions are mainly distributed near rivers or lakes. The area with buried depth of groundwater level lower than 5.0m belongs to desert region.

Code of abstract: T7.3.7
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Characteristics of groundwater and surface water in dune slacks in north-west Ireland under differing management regimes

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KEY WORDS dune slack, groundwater-dependent terrestrial ecosystem, hydrology, water chemistry, land management

ABSTRACT
Dune slacks are groundwater-dependent seasonal ponds in sand dunes that act as a refuge for wetland species. Within the European Union, their dual protection under the Habitats Directive and the Water Framework Directive is a reflection of their conservation value. Many European dune slacks are protected within conservation areas and are subject to non-intensive land use. Hydrology and hydrochemistry have been shown to be major drivers of dune slack condition in barrier islands and spits and in sites with a history of high anthropogenic pressures in continental Europe but relatively little research has been carried out on the effects of low- to moderate-intensity land management in sand dunes on water levels and water chemistry of dune slacks.
We compared the relationship between groundwater levels and rainfall at six sites in north-west Ireland, characterised the hydrochemistry of ground and surface water and compared groundwater chemistry and hydrology for two major Irish sand dune land uses: non-intensive pasture and golf courses. Groundwater levels at the three dune slacks in sand dune systems with lowest elevations responded more swiftly to rainfall events than the three more elevated sites, and this is consistent with an influx of surface water from surrounding areas moving into the low-lying dune systems. This implies that shallow aquifers of low-lying sand dune systems are more vulnerable to contamination from sources outside of the dune system than sand dunes which are more elevated in relation to the surrounding landscape. At four sites, chemical indicators of denitrification were present in groundwater. This suggests that natural attenuation processes may mitigate the impact of nitrogen inputs so that the dune slack ecology is not affected. Maximum water table height and seasonal water level range were greater in pasture sites than golf course sites. This may be due to the fact that water is pumped off two of the golf course sites to prevent flooding after heavy rains, which could affect the maximum height of the water table. Over time, a reduction in the maximum water levels of dune slacks is likely to result in a reduction in the total area of dune slack habitat. Our findings highlight the importance of considering land management impacts in the wider landscape when managing groundwater-dependent habitats.

Code of abstract: T7.3.8
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Groundwater-surface interactions in a boreal forest-fen catchment – a modelling case study of Pallaslompolo, Finnish Lapland

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KEY WORDS groundwater-surface water interactions, boreal, carbon balance

ABSTRACT
The northern terrestrial ecosystems are important carbon sinks globally storing up to 1715.8 Pg of carbon. This carbon may be partly released as an effect of global warming. Thus, it is of high importance to understand the dynamics of carbon fluxes between atmosphere and these ecosystems in the face of changing climate. One of the governing factors on the total carbon balance is a local hydrology. Recent studies indicate that exceptionally wet or dry conditions may transform some boreal ecosystems from net carbon sinks to net carbon sources. In this view, better understanding of boreal hydrology across various boreal landscapes is crucial for evaluation of future climate on the net carbon balance.
The Pallaslompolo catchment is a small watershed (~6 km^2) located near the fell chain of Pallastunturit within the north boreal zone. The bottom of the watershed valley consists of open, nutrient-rich sedge fens, whereas adjacent hills are mainly covered by Norway spruce forests and are underlain by glacial till soils. The Pallaslompolo watershed discharges to the large headwater lake of Pallasjärvi and it is part of an atmosphere-ecosystem supersite – a joined initiative of numerous Finnish institutes to conduct a wide range of environmental studies.
The previous carbon balance studies indicate that the groundwater significantly contributes to carbon transport within the area. To investigate the role of the external groundwater in the carbon fluxes of this fell-fen system, we will build a transient physically-based groundwater-surface water model of the site using HydroGeoSpehere software. Special attention will be put on proper conceptualization of winter processes that play a crucial role in the site hydrology. The model will be parametrized using measured data and calibrated to match various types of observations: discharge measurements, groundwater levels, soil moisture, soil depths and eddy covariance observations of evapotranspiration. To enhance model verification, we evaluate the amount and spatial extent of groundwater infiltrating to mire and its effect on the run-off generation using stable water isotope methods (sampled during summer 2017). The preliminary results of modelling and ancillary field measurement will be presented.

Code of abstract: T7.3.9
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Variation of wetlands and its response to groundwater dynamics in an arid region

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KEY WORDS
MODIS data, NDWI, wetlands, soil moisture, Qaidam Basin

ABSTRACT
We present a regional framework for the spatiotemporally distributed assessment of variation trends of wetlands in arid basin where natural ecosystems are highly groundwater dependent. To achieve this, the recent trends (from year 2001 to 2014) in wetlands, precipitation and soil moisture were analysed using a combination of satellite data and ground-based observations. The trend assessment was applied for the arid Qaidam Basin, one of the largest inland basins in China.

The Qaidam Basin is located in north part of Tibet Plateau which covers a surface area about 276,233 km^2. With elevations ranging from 2600 to 6600 m above sea level, there are extensive plains in the central areas. The region has a typical arid to semi-arid climate with a average yearly precipitation spatially raging from 15 mm in the west parts up to 200 mm in the east areas.

MOD09A1 data of summer from 2001 to 2014 formed the core datasets for time series variation of wetlands and the Normalized Difference Water Index (NDWI) was selected as main method for identify the wetlands in Qaidam Basin.

The results revealed a significant increasing trends in wetlands areas during the period of 2001-2010 and the maximum area of 2010 was 3147 km^2. On the opposite, the decreasing trend of wetlands areas was observed after 2010. The distribution of wetlands was more spatially concentrated in the plain area, with elevations smaller than 3000 m. There is no significant trend was observed for precipitation from 8 meteorological stations and it cannot explain the wetlands change. Based on GLDAS data, a similar temporal distribution trend of soil moisture in layer 100-200 cm underground was observed and there is strong positive correlation between variation of wetlands and soil moisture (R^2=0.93). Hence, the wetlands trends in the Qaidam Basin can mainly be attributed to the effects of groundwater dynamics and the wetlands can be classified as groundwater-dependent ecosystems.

Code of abstract: T7.3.10
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Sediment transport in relation of forest cover progression in a small scale Mediterranean catchment

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KEY WORDS: sediment transport, catchment, forest progression, flow off

ABSTRACT

Decrease of sediment transport is one of the major indicators of forest ecosystem stability. Forests have highly performing regulatory functions on the water cycle among others especially in Mediterranean environments characterized by high temporal contrasts in weather conditions.
Sediment transport is a specific form of soil particles movement in the catchments which takes place due to complex interaction processes between topographic, hydrological and geological characteristics, climate, soil, vegetation cover, and human activities.
The aim of this study was to assess the effect of forest vegetation in decrease of sediment transport – soil loss. To improve that statement, experiment was conducted in small Mediterranean catchment, Suvava (Central Dalmatia, Croatia). The catchment covers area of 1823 ha, with the length of the main stream of 10.1 km and the entire length of greater and smaller tributary streams of 20.8 km. Altitude is between 460 and 961 m above the sea level. The soil is classified as marl limestone, shallow and very skeletal.
The climate is sub-Mediterranean, average annual precipitation is 1200 mm and average annual temperature is 13°C. The rainy season takes place from October to April, though summers are hot and very dry. The main land uses are: forestry 60 % (pine and oak), followed by shrub area 20%, agricultural areas 15 % and bare area 5%.
Monitoring began in Suvava catchment in 1972 and lasted until 1975. In 2009 monitoring was re-established.
The equipment in the catchment provided information about meteorological variables, water level and water flow (discharge). For each event, rainfall and runoff volumes, runoff coefficient, and peak flow were determined. All these variables, as well as sediment transport, were analysed to characterize the hydrological functioning of the catchment.
The results obtained were compared to those from the previous period (1972-1975) when the catchment was under human disturbance, cultivated and grazed. In above mentioned period, the catchment was covered by pine and oak forest (20 %), shrub (5%), agricultural land 15 % and bare land 55 %. The obtained results demonstrated that sediment transport is significantly lower nowadays when 60 % of the catchment area is covered by forest compared with the period from the 1972 to 1975 when only 20 % was covered by forest. Annual runoff coefficients are low and do not exceed 10 % in both periods. Forest cover in the catchment significantly reduced sediment transport.

Code of abstract: T7.3.11
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

Environmental monitoring and forest-water relationship in Mediterranean forest ecosystems

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KEY WORDS: Mediterranean forest ecosystems, environmental monitoring, ecological functions, nutrients, contaminants

ABSTRACT

Mediterranean forest ecosystems in Croatia are of very high significance because of ecological functions they provide. Mediterranean forests are, besides of its multiple goods and services largely related to their environmental and social functions. The risk of impacts of air pollution, erosion, landslides and floods is being so high in this region. These risk factors combined with climate change are likely to affect nutrient turnover and nutrient availability, soil moisture and, ultimately, growth and primary productivity. These forest ecosystems cover almost half of Croatian total forest area. They are under the combined influence of local, regional and long-distance pollution sources. The atmospheric deposition and its transformation in contact with vegetation are of great importance in understanding its effects on forests. It has an impact on forest ecosystem through eutrophication by nitrogen and soil acidification, altering soil properties and processes. Changes in the soil chemistry may lead to imbalances in the nutrient supply and subsequently to unbalanced nutrition of the trees. Fluxes of nutrients, contaminants and other elements within forest ecosystems are important indicators of ecosystem functioning and stability. Important fluxes include uptake by plants, fluxes associated with soil processes, and leaching into surface waters and ground waters. The conversion of precipitation to groundwater is reduced by the interception of forests and by evaporation from the tree canopy. It is reduced further through transpiration of soil moisture from foliage. These can be described as losses to the useful water system in forest. The changes in tree growth and crown condition, in most cases, are a result of a multitude of stress factors including atmospheric inputs and rapidly changing climatic condition. In order to fill in the knowledge gap, the monitoring plots are set up in different Mediterranean forests ecosystems and intensive environmental monitoring has been organized. Based on the obtained data we will estimate the impact of acid and nutrient deposition on nutritional status of soil and foliage, water availability, tree crown condition and growth as well as the cause-effect relationships between the health status of forest ecosystems and natural and anthropogenic factors.

Code of abstract: T7.3.12
Type of presentation: Poster presentation
Topic: T7. Groundwater and Dependent Ecosystems
Session: T7.3. Groundwater and terrestrial ecosystems

„Field investigations on the behavior of Sulfamethazine and Tetracycline in soil and groundwater“

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KEY WORDS - liquid manure, soil water, antibiotics, transport, degradation

ABSTRACT
Entry, behavior and fate of pharmaceutical residues in the terrestrial and aquatic environment became focus of various research studies in the field of hydrology and other branches of research. Problematic consequences of pharmaceutical residues in the environment are, amongst others, bacterial resistance and adverse effects on non-target organisms. Pharmaceuticals may enter the environment via different pathways, for example by application of manure on agricultural used fields from animal farming. Parameters which are supposed to strongly influence the agents on their way from entering the soil, accumulating in or passing through the unsaturated zone and infiltrating into the groundwater are still insufficiently investigated yet.

In order to close identified knowledge gaps, field investigations on the behavior of various veterinary pharmaceuticals take place considering saturated and unsaturated conditions. After application of manure - extracted from pig farming and spiked with the target substances – the fate of the substances is observed from topsoil to groundwater with a primary focus on sorption and mobility of the target substances in the unsaturated zone, degradation rate constants and infiltration quantity into groundwater. At the study site, an agricultural used field with maize cultivation, suction cups were installed for extraction of the soil water. Additionally, observation wells along a downstream transect were sampled for groundwater monitoring. The samples were processed via solid-phase extraction. The analytical method is based on liquid chromatography separation coupled to tandem mass spectrometry detection (LC–MS/MS).

The presented poster shows the behavior of Sulfamethazine and Tetracycline under field conditions, as these compounds are intensively used antibiotics and frequently administered in productive livestock.

Code of abstract: T8.1.1
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Characterizing Permeability in Deep Aquifers

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KEY WORDS permeability, core testing, drillstem tests, scale, deep groundwater

ABSTRACT

Characterizing deep groundwater systems is an emerging challenge in hydrogeology. Deep aquifers are targets for fluid disposal, geothermal energy development and water resources for industrial use. Data is scarce in these environments due to the cost of drilling and testing. Conventional pumping test analysis is generally not possible because of the cost of installing observation wells. Permeability estimates are commonly made through analysis of single well tests, laboratory testing of core and regional models. These tests provide slightly different results because of their orientation, scale effects and sampling bias. Here we examine different tests from a number of clastic and carbonate aquifers in the Western Canada Sedimentary Basin. Permeability tends to be higher in methods with larger support volumes is not statistically significant in all cases.

Code of abstract: T8.1.2
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

3D coupled fluid- and heat flow modelling of the subsurface of Berlin, Germany

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KEY WORDS Geothermal energy, 3D Thermohydraulic modeling, Boundary Conditions, Anthropogenic alteration, Urban

ABSTRACT

The major objective of this study is to understand the complex configuration of the fluid flow and geothermal field below the urban center of Berlin, capital city of Germany. To achieve this goal newly available hydraulic and thermal data (e.g. groundwater recharge rates, groundwater wells and surface temperatures) were implemented into an existing 3D model of coupled fluid and heat flow.
The area of interest is located in the Northeast German Basin, consisting of an infill of several kilometers of sediments which also contain two units of particular interest for geothermal exploration. Namely these are the Triassic Middle Buntsandstein and the Permian Sedimentary Rotliegend, which both display favorable hydraulic properties for geothermal exploration. The hydrogeological configuration of the shallow subsurface depicts two distinct compartments, where deeper saline aquifers are separated from overlying shallow fresh water aquifers by the partly discontinuous Paleogene Rupelian clay aquitard.
In earlier studies we were already able to outline, that the geothermal field is mainly influenced by existing contrasts in the thermal and hydraulic conductivity between the different model units. Specifically the highly thermally conductive Permian Zechstein salt and the lowly hydraulically conductive Paleogene Rupelian Clay distinctively shape the distribution of subsurface temperatures. A strong coupling to the prescribed hydraulic and thermal boundary conditions can also be observed whereas the hydraulic boundary condition effectively controls the nature and vigor of fluid flow, i.e. forced convective cooling of the deeper subsurface. In this context, this study aims to analyze the quantitative and qualitative impact of modifications to or different implementations of the hydraulic and thermal boundary condition.

Code of abstract: T8.1.3
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Influece of dynamic viscosity in geothermal Open Loop Systems modelling

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KEY WORDS -Open loop system; Thermal Affected Zone, Dynamic viscosity, Heat transport, Feflow.

ABSTRACT
The Groundwater Heat Pump (GWHP) system is a technology that withdraws water from a well, passes it through a heat exchanger and discharges the water into an injection well or nearby surface water. This system, utilizes the relatively natural stable temperature of groundwater and depending on the use mode (heating or cooling), energy can be extracted or injected. Consequently, the ambient aquifer temperature is disturbed, and a thermal plume of colder or warmer re-injected groundwater, known as the Thermal Affected Zone (TAZ), develops.
The determination of the TAZ around the injection point is a fundamental aspect even before the construction of the groundwater open-loop geothermal system. Physical processes affecting heat transport within an aquifer include advection (or convection), mechanical dispersion and diffusion (usually grouped into hydrodynamic thermodispersion).
The results of a sensitive analysis indicates that the main hydrodynamic parameters that influence the heat transport are hydraulic conductivity and gradient. As the hydraulic conductivity varies according to the temperature due to the variation of the water dynamic viscosity, in the present study we check which is the influence on heat transport of the groundwater temperature variation induced by an open-loop system reinjection system.
To investigate this topic a sensitive analysis has been realized using FEFLOW® 6.2 package. Two different scenarios have been considered as FEFLOW gives the possibility to include or disregard the dynamic viscosity variation related to the groundwater temperature. The two scenarios analysed highlighted that the variation of the dynamic viscosity with the groundwater temperature affects the extension of the TAZ. The modelling context in which the dynamic viscosity variation should be taken in to account to correctly assess the subsurface thermal perturbation are highlighted.

Code of abstract: T8.1.4
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

A Multi-scale Approach toward understanding the Hydraulic Characteristics of the Stimulated Fractured Crystalline Rock

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KEY WORDS - hydraulic characterization, hydraulic stimulation, permeability enhancement, fracture, crystalline rock

ABSTRACT
The presence of natural and induced fractures introduces heterogeneity and anisotropy to the dominant flow paths in the subsurface media such as fractured aquifers, oil and gas reservoirs, nuclear waste repositories and enhanced geothermal systems. In such environments, characterization of the fractured medium through a combined multi-scale and multi-component approach could result in an improved understanding of the physical setting and behavior of the medium of interest in order to move toward a sustainable reservoir management.
As part of the In-situ Stimulation and Circulation (ISC) experiment at the Grimsel Test Site (GTS), which is located in the central Swiss Alps, an extensive hydraulic characterization campaign has been conducted in order to evaluate the efficiency of various hydraulic stimulation methods such as hydraulic fracturing and hydraulic shearing on the EGS reservoir creation. The main objectives of this campaign are the quantification of permeability enhancement and heat exchange efficiency of the granitic host rock. The hydraulic characterization consists of tests of varying scale, ranging from single-hole (e.g. pulse injection and oscillatory injection tests) to cross-hole (e.g. constant rate injection and oscillatory interference tests) and reservoir scale (e.g. long-term constant rate injection test, step-pressure tests). Moreover, various components in addition to hydraulic tests have been added to these measurements such as thermal and conservative tracer tests, single-hole and cross-hole geophysical measurements and strain/deformation measurements.
The results obtained indicate enhancement of permeability as well as non-integer flow dimension, and thereby natural heat exchange efficiency of the fractured zones. In addition to that, the characteristic of the thermo-hydro-mechanical (THM) behavior on the influenced fractures during the hydraulic/thermal characterization tests has been affected as more flow paths now contribute to the hydraulic system as a direct response to hydraulic stimulation. Finally, combinations of all above-mentioned methods provide new insights on the heat exchange efficiency of the stimulated rock mass.

Code of abstract: T8.1.5
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Groundwater budget calculation of the Riardo Plain aquifer (Southern Italy) for conjunctive sustainable uses.

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KEY WORDS - Groundwater budget calculation, Mineral water, Mineral water bottling, Sustainable use,

ABSTRACT
Any groundwater resource management must be informed on the geology and hydrogeological settings at the basin scale for a sustainable use of the aquifer, especially when exploited for several purposes (agricultural, mineral water bottling, municipal and domestic withdrawals). The variability in time of the groundwater resource requires long time monitoring of the whole system to accurately evaluate the terms of the hydrogeological budget. A reduction of rainfall or the overexploitation of the aquifer could cause a progressive deployment of the resource and a negative budget discrepancy. Anyway, in case of a budget deficit, groundwater levels and springs flow rates might remain unchanged due to a possible groundwater contribution from external areas. This recharge, not quantifiable through field data, could constitute a fundamental rate of available resource that must be evaluated to plan the sustainable use of groundwater resource. These conditions seem to be present in the Riardo Plain aquifer (North of Campania Region - Italy), a strategic drinking resource for more than 100.000 people and unique source of Ferrarelle mineral water bottling plant. The present study is aimed at improving the knowledge of the recharge processes of the aquifer through an update of the water budget and the comparison with the groundwater level and outflows variations during the last twenty years. Former hydrogeological studies highlighted the presence of several local overlapping aquifers over a productive basal aquifer with a radial flow, which laterally recharge the surrounding plains. A deeper carbonate aquifer shows the same water level of the upper volcanic one, and local groundwater mixing processes allow the formation of the Ferrarelle mineral water type. The mean groundwater recharge of the Riardo Plain aquifer in the 2000-14 interval was calculated using thermo pluviometric data acquired in 18 weathering stations and elaborated using Thornthwaite's method. The mean natural discharge of the aquifer was measured during several hydrogeological surveys. Agricultural, human, mineral bottling withdrawal were estimated to obtain a reliable groundwater budget result. A significant deficit was obtained in the study area as the outflow seems to exceed the infiltration approximately of 40% of the total recharge. Weekly groundwater level monitoring and seasonal discharge measurement of the natural outflows during the study period show almost stationary water levels. These observations suggest the presence of an external deep recharge, probably from the surrounding carbonate ridges, but not exactly defined yet. The contribution of a wider recharge area allows to maintain the Riardo Plain aquifer less vulnerable to possible future variation of the zenithal recharge. This result represents an essential information to start a quantitatively-based sustainable aquifer management.

Code of abstract: T8.1.6
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Safety of groundwater resources in terms of development of shallow geothermal energy installations

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KEY WORDS shallow geothermal energy, risk to groundwater resources, heat pumps

ABSTRACT
As proved by the *Market Report 2015* of the European Geothermal Energy Council and publications of the World Geothermal Congresses a substantial growth in use of shallow geothermal energy has been noticed in Europe over the recent years, both in terms of installed total capacity and number of installations. Dynamic development has been set off by a need for improvement of air quality through reduction of CO2 and dust emissions and necessary compliance of practices with the international, EU and country's policy and legal regulations.
This presentation illustrates selected examples of threats which might be posed by the installations using low enthalpy geothermal energy on groundwater's quantity and quality. It also proves how crucial a detailed geological survey and knowledge about local settings in the process of design and completion of these installations is. The presented examples derive from the Geothermal4PL project supporting sustainable development and use of shallow geothermal energy in Poland and the areas of the *Mieszkanie Plus* national housing programme.
Installation of heat pumps in open and closed-loop systems for heating and cooling requires digging and boring and results in disruption of underground including rocks and groundwaters. The extent and character of induced changes depend on depth of installation, geological and hydrogeological settings and other conditions, such as: installation type (vertical, horizontal, thermal poles), mode of use (heating only, heating and cooling) and in some instances can be harmful to groundwater resources.
In case of horizontal installations the heat exchanger is buried up to 1-2 metres of depth so disturbance and risk are limited. Possibility of threat to the environment is larger for the vertical heat exchangers mounted as the closed-loop system in the boreholes which depth normally varies between 50 to 200 metres. Those, if improperly made may perforate aquitards and connect aquifers different with respect to hydrodynamics and chemistry. Typical problem for the open systems using groundwater as a medium is well clogging and corrosion due to bacteria mediated iron and manganese precipitation. For the closed-loop systems, using mixtures of organic compounds as a medium, an accidental leakage contaminating rocks and groundwater causes a certain risk.

Acknowledgements
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Code of abstract: T8.1.7
Type of presentation: Poster presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Prediction of deep mining water discharge in Wushan Copper Mine

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KEY WORDS: mining water discharge, numerical simulation, negative exponential model, principle of equivalent permeability coefficient

ABSTRACT:
Wushan Copper Mine belongs to a large scale underground mining Copper in China, it has two ore belts in the south and north. Currently, the mining level of Wushan Copper Mine has reached to 360m beneath the ground.
In this study, we employed numerical simulation to predict the deep mining water discharge. During the deep mining water calculation, we used the negative exponential model and the principle of equivalent permeability coefficient to solve the discontinuity problems during the process of deep water drainage. During the model uncertainty analysis, we analyzed the advantages and disadvantages of global and local sensitivity coefficients on the model uncertainty. The orthogonal test method which can make up the defects of the local and global sensitivity analysis, was also introduced into the model uncertainty analysis. Based on the uncertainty analysis and simulation, we obtained the mining water discharge at various depth. The results showed that at the mining level of -360m, the maximum mining water discharge in the south ore belt was 10442.80-10902.60m^3/d, while in the north ore belt it was 5456.61-5749.41m^3/d, when the depth was -1210m, the maximum mining discharge increased to 14562.62-18582.01m^3/d and 7130.88-9461.77m^3/d in the south and north ore belt, respectively. The calculation can provide safety evidence for copper production of Wushan Copper Mine.

Code of abstract: T8.1.8
Type of presentation: Poster presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.1. Groundwater and Energy

Numerical study on heat transport in non-uniform aquifers

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KEY WORDS - heat transport, stochastic fractal, hydraulic conductivity, advection dispersion analysis, numerical simulation

ABSTRACT
As heat utilization in aquifers in urban areas, there are use as heat sources in aquifers with high flow rate, and utilization of heat storage in aquifers with low flow rate. In any case, in order to properly judge the availability of the project, a simulation method concerning heat transport in the aquifer is important, as well as an efficient in-situ survey method. On the other hand, when mathematically dealing with heat transport in the aquifer, advection dispersion analysis is generally used, but a method of setting the macroscopic dispersivity, which is an important parameter, has not been established. In addition, since the water density and the viscosity depend on the water temperature, analysis of the flow field is complicated, so there are few analysis examples. In this study, artificial non-uniform hydraulic conductivity fields were generated by using the stochastic fractal model, then 3D numerical simulations of the advection dispersion analysis were carried out to demonstrate the characteristics of heat transport in non-uniform aquifers.

Code of abstract: T8.2.1
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Delineation and characterization of geothermal reservoirs in the Southern part of the Pannonian Basin

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KEY WORDS: thermal water, geothermal reservoirs, Pannonian basin, resource assessment

ABSTRACT

The Renewable Energy Action Plans of most of the countries in the Danube Region foresee a 3-3,5 folds increase of geothermal heat production from 2010 to 2020. From the resource side, the abundant availability of thermal groundwater in the S-ern part of the Pannonian basin can fulfil this increased demand, however to implement these ambitious goals, an elementary knowledge on the spatial distribution and main characters (porosity, permeability, temperature, chemistry of stored waters) of the hydrothermal reservoirs is necessary, which is also required by any further management issues, e.g. site selection of new projects, release of additional production licences, etc.

In the case of large, extended transboundary geothermal aquifers with multiple users having cumulative impacts by their thermal water abstractions, it is of utmost importance to have a joint and regional understanding of the reservoir dimensions and properties irrespective of state borders in order to guarantee sustainable production levels. Although the basic types of geothermal aquifers and their extension at basin scale are relatively well known in the Pannonian basin, clarifications of the same reservoirs vary in the neighbouring countries resulting from using different geological nomenclature for the same formation, different understanding of the thermal water flow systems, dissimilar models of the subsurface temperature field, etc.

The Danube Transnational Program funded DARLINGe project (www.interreg-danube.eu/darlinge) aims to support a harmonized and integrated thermal groundwater and geothermal energy utilization management among Hungary, Slovenia, Bosnia and Hercegovina, Croatia, Serbia and Romania at the southern part of the Pannonian basin, and as such to provide a good example for other regions sharing transboundary geothermal aquifers.

A harmonized methodology of outlining and characterizing large transboundary hydrothermal reservoirs based on common geological, geothermal and hydrogeological dataset of six countries has been elaborated. In addition to the identification and characterization of the reservoirs, a probabilistic resource assessment of the recoverable thermal energy has been carried on by Monte Carlo simulation method.

Code of abstract: T8.2.2
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Groundwater and Unconventional Oil and Gas Developments

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KEY WORDS unconventional oil and gas, hydraulic fracturing, baseline assessments

ABSTRACT

Groundwater is impacted by energy production globally. Many of these areas have been producing oil and gas for nearly a century, while new and "unconventional" techniques have recently created opportunities for extracting these resources in new areas. Strong opposition to resource development often occurs in regions that are new to oil and gas development. Uncertainty about potential impacts to groundwater resources is a common reason for this opposition. However, without oil and gas development or a substantial investment in baseline testing, quantifying the risk of impacts can be quite difficult. Meanwhile, in areas with extensive historical development, impacts to groundwater resources have not been a major impediment to the industry. Whether this is because such impacts are rare or because they have not been well documented in unclear. A closer examination of baseline assessments, monitoring and impacts in areas with extensive oil and gas development in diverse locations globally should provide insights into appropriate assessment strategies and likely impacts in areas new to oil and gas development.

Code of abstract: T8.2.3
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Approach to Exploration of the East Croatian Transboundary Geothermal Deep Water Bodies

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KEY WORDS Geothermal Energy, Geology of Deep Water Bodies (GDWB), Hydrogeochemistry, East Croatian Pannonian Basin

ABSTRACT
Geothermal Deep Water Bodies (GDWB) of the Croatian Panonian basin, in Vukovar-Srijem County, are largely described in published general geological and hydrocarbon exploration/production studies. The Croatian government owns information that can cut future geological risk. GDWB are confirmed in the fractured carbonates under the basin cover at Babina Greda able for electric power production, and in the sand reservoir "Županjski pješčenjaci" at the Bošnjaci field used for direct heating.
The considered transboundary geology discusses: crustal buildup, lithology, age and forming environment, tectonic events, recent stress, thermo - and hydrodynamics. Geological column here starts from older Paleozoic & Mesozoic environments and consolidations represented by: schist, granite-gneiss, diabase, gabbro, carbonates and other rocks below Pannonian basin fill, partly represented by carbonates and volcanic intrusions, prevailingly clastics: shale, marls and clays inter-bedded with sandstone reservoirs.
The most important GDWB are occurring in fissured rocks and karstified carbonate bodies, secondary porosity type systems in intergranular reservoirs such as sands sandstones. The increased geothermal flow in this area is related to thermal conductivity through thinned crust and fluid convection, particularly of the geothermal waters in the mighty GDWB.
A special advance is the interpretation of the spatial distribution of geothermal gradients, thanks to the recent positive approach by established formation temperatures. Their geothermal energy efficiency will not be considered here.
Hydrogeochemical analysis is another challenge in further exploration. According to hydrogeochemical characteristics almost potable water is present in the shallower GDWB basin layers, but also in deeper fractured massive carbonates and some fissured rocks below basin fill. Meanwhile, saline and very saline waters are common in deeper parts of the basin fill, and they are generally less attractive in GDWB delineation.

Code of abstract: T8.2.4
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Possibilities of finding geothermal water for heating purposes in the Town of Vukovar (Croatia)

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KEY WORDS geothermal prospection, hydrocarbon wells, permeable intervals, geothermal gradient, hydrogeochemistry

ABSTRACT
Initial study of the possibilities of finding geothermal water was conducted in the Town of Vukovar, which is interested in utilizing this renewable energy resource and reduce the dependence on expensive imported gas for district heating purposes. The initial study was done based on the existing data from hydrocarbon research (seismic reflection, borehole data and water sampling).
Unfortunately, seismic reflection profiles were not available for the area of the town itself. Since it is of interest to drill a well on the territory of the town and as close as possible to the future users (central heating stations), the profiles were not considered in the interpretation.
Rocks and sediments with satisfactory hydraulic properties have been determined during hydrocarbon research of the Vukovar area, and it is expected that the Upper Pannonian *Abichi* deposits (sands and sandstones) represent geothermal aquifers. On the basis of the data from resistivity and spontaneous potential logging, favourable intervals have been determined at depths ranging from 800 to 1700 m.
Geothermal gradient was determined on the basis of thermal logging and maximum temperature measurements. Usually the gradient obtained by using T_{MAX} is higher than the one obtained by logging, due to the technology of measurement. In Vukovar area, data from seven boreholes were available: 6 thermal logs and 1 T_{MAX}. The determined values were 34-43 °C/km. Slightly elevated geothermal gradient was determined, which is in accordance with the position of research area on the southern rim of the Pannonian Basin System, a known positive geothermal anomaly due to crustal thinning. Data for the wider Vukovar area (Eastern Slavonia Basin) have shown gradients of 51-53 °C/km.
Water samples were only taken in one out of seven boreholes, at two depths. Waters show a similar hydrochemical facies (Na-Cl type) which, in the context of hydrochemical model of Pannonian Basin System, represents waters that infiltrated formations during Miocene transgression and achieved chemical equilibrium with rock matrix. Anionic composition also shows characteristics of mature waters, i.e. waters with long residence time which achieved chemical equilibrium with the surrounding porous medium.
After analysing the existing data, guidelines for the next phase of research were given.

Code of abstract: T8.2.5
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Review of Water Risks Related to Unconventional Oil Production in the U.S.

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KEY WORDS energy extraction, hydraulic fracturing, oil and gas production, tight oil production, unconventional shale oil production, produced water

ABSTRACT
Major unconventional tight oil plays are mostly in semiarid regions in the western U.S. with water risks related to sourcing of water for hydraulic fracturing and disposal of produced water. Here we compare water risks for oil plays, including water scarcity issues related to hydraulic fracturing, produced water volumes and related induced seismicity using data from the Eagle Ford, Permian, Oklahoma, and Bakken tight oil plays. Water use for hydraulic fracturing increased by up to a factor of 10 in many of these plays within the past 5 – 10 years. Operators have adapted to water scarcity issues by expanding the variety of water sources from freshwater to brackish groundwater, municipal waste water, and reuse of produced water. Produced water volumes from tight oil reservoirs is highly variable. Most produced water is disposed of in non-oil producing geologic units and has been linked to induced seismicity in some regions, particularly Oklahoma. The quality of produced water is highly variable, with total dissolved solids exceeding that of sea water by up to a factor of 10 or more in some plays. Various strategies are being considered to manage produced water volumes, including reuse for hydraulic fracturing, disposal in pressure depleted conventional oil reservoirs, evaporation in surface ponds, and irrigation. Water risks related to tight oil production in the U.S. are evolving rapidly; however, various strategies are being developed to manage these risks.

Code of abstract: T8.2.6
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Towards a more efficient and sustainable use of deep geothermal energy resources in the S-ern part of the Pannonian Basin, Central Europe – the DARLINGe project perspective

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KEY WORDS: thermal groundwater, direct use, Pannonian basin, transboundary aquifer, management

ABSTRACT

The Pannonian Basin in Central Europe is well-known of its outstanding geothermal potential and being rich in thermal groundwater which is widely used for balneology and to a less extent for direct purposes (district heating, individual space heating of communal buildings and in the agriculture sector).

A major challenge for this region – which is highly dependent on the import gas from Russia – is to endorse geothermal energy into its energy mix, especially into the heating sector which accounts for 40% of primary energy consumption and for a significant share of CO_2 emissions. Utilizing the still untapped deep geothermal energy resources of the Pannonian Basin - a classic example of hot sedimentary geothermal play type - may provide a promising solution, however has to be planned with an extreme care, as the unfavourable effects of excessive thermal water production by multiple users might affect distant parts of the large geothermal aquifers, where significant basin-scale cross-border groundwater flow also occurs.

To meet the challenge of boosting the sustainable utilization of the existing, however still largely unexploited deep geothermal resources at the S-ern part of the Pannonian Basin, partners from six countries work together in the DARLINGe project (www.interreg-danube.eu/darlinge) supported by the Danube Transnational Program. The project area covers territories of S-Hungary, NE-Slovenia, N-Croatia, N-ern parts of Bosnia and Herzegovina, N-Serbia and W-Romania, altogether about 95000 km^2. The paper presents the overall approach, as a market replicable methodology and main activities of DARLINGe, highlighting its main innovative characters of outlining and characterizing transboundary hydrothermal reservoirs based on harmonized geological, hydrogeological and geothermal models, the functions and contents of the planned Danube Region Geothermal Information Platform (DRGIP, an interactive web-portal to support decision making), as well as the elaboration of a tool-box consisting of 3 complementary modules for sustainable geothermal reservoir management to be tested and verified in 3 cross-border pilot areas:

- an independent indicator based benchmark evaluation of current uses,
- a decision tree to provide a step-by-step guide to project developers,
- a geological risk mitigation scheme to maximize the success rate of a first geothermal well

Code of abstract: T8.2.7
Type of presentation: Poster presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Challenges of sustainable use of groundwater resources in an urban area (Ljubljana case study)

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KEY WORDS groundwater, shallow geothermal energy, urban area

ABSTRACT
Global trends and projections of population growth show that in the future big majority of the world's population will be living in urban areas. To meet increasing energy and drinking water needs cities will have to use natural resources more efficiently and sustainability will have to become the key concepts for planning the future cities. The basis for this is understanding of natural conditions and awareness of potentials and limitations for the utilisation of the resources. The city of Ljubljana, capital of Slovenia, has a long tradition of using groundwater resources beneath the city for public drinking water supply. The hydrogeological properties of the subsurface provide also favourable conditions for implementation of geothermal heat pump systems which represent one of the key technologies for heating and cooling amongst renewables. At the moment the geothermal potential of groundwater resource is not used efficiently. One of the main reasons for that is lack of geological information about the potential and limitations for the implementation of shallow geothermal systems. To bridge this gap quantification of shallow geothermal potential has been started. Together with development of tools for presentation of natural potential and risks for shallow geothermal utilization will provide a solid basis for development of energy management strategies of the city of Ljubljana and help to meet its environmental objectives – reduction of hazardous gas emissions and increase the share of renewable energy in final energy consumption.

Code of abstract: T8.2.8
Type of presentation: Poster presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.2. Geothermal reservoirs and their potential

Geothermal potential of Krapinsko – Zagorska County - Croatia

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KEY WORDS: thermal groundwater, water temperature, utilization, Krapinsko – Zagorska County

ABSTRACT

Favourable geothermal properties which are characteristic of the major part of the Pannonian basin also extend into its south-western margin where Croatia is situated. The Krapinsko –Zagorska County is situated in the Pannonian part of Croatia, in its north-western part, and there are lot of natural thermal springs which are used mainly in balneology and less in other purposes (district heating, individual space heating of communal buildings and in the agriculture sector). The modes of utilization vary according to water temperatures, e.g. waters of the lowest temperatures are used for the public water supply, bottling and fish farming, while waters of the highest temperatures are utilized for water and space heating. Since the production of energy for heating households, industry, buildings etc. in the county territory depends on the import gas from Russia it is advisable to endorse geothermal energy into its energy mix, especially into the heating sector which accounts for 40% of primary energy consumption and for a significant share of CO_2 emissions. During the DARLINGe project which is supported by the Danube Transnational Program, will be boost the challenge of the sustainable utilization of the existing thermal groundwater resources in the county area. The most important localities in the county territory where thermal waters occur or they were drilled are: Harina Zlaka, Kumrovec, Stubičke Toplice, Krapinske Toplice, Tuheljske Toplice, Jezerčica, Šemničke Toplice and Gotalovec. According to the water temperature, thermal waters in the county territory are range from subthermal to hyperthermal (22 – 45 ^oC). According to the major ionic composition, water from Stubičke toplice belong to a CaMgNa-HCO_3SO_4 mixed type; while the rest of thermal waters belong to the CaMg-HCO_3 type The most diversified use is accounted for in Stubičke toplice: recreation, balneotherapy, water and space heating, greenhouse heating and sanitary water.

Code of abstract: T8.3.1
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Can elevated uranium concentrations in groundwater be predicted?

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KEY WORDS - uranium, groundwater, predictive modeling, hydrochemical parameters, aquifer lithology

ABSTRACT
Uranium concentrations in groundwater are generally low, typically in the range of 0.1 to 1 µg/L, but it can reach several tens of µg/L in certain circumstances. Despite its well-known toxicity uranium concentrations are not routinely determined in regional groundwater quality assessment. The aim of this study is to improve the understanding and predict the factors associated with high U concentrations in groundwater from specific geochemical environments. Sampling survey covered 155 different groundwater sources including wells and springs unevenly distributed in different parts of Serbian territory. Non-parametric statistical analysis was applied to examine the relationship of U enrichment in groundwater with major element concentrations (Na, Ca, Mg, Si, HCO_3, Cl, SO_4), physico-chemical parameters (pH, EC, Eh, T) and geological formations. Three major hydrochemical facies have been identified based on the major ion chemistry: Na-HCO_3, Ca-HCO_3 and Mg-HCO_3 water type. Water temperatures ranged between 8 and 106 °C, Eh values from −226 to 441 mV, EC between 95 and 10.240 µS/cm, and pH values were slightly acidic to alkaline (5.83–9.7). Data analysis of U concentrations indicated the existence of two data populations: one with predominately low U values (<0.43 µg/L below the 75th percentile) and another population with extreme U values (up to 14.5 µg/L). Anomalous uranium concentrations were observed in Na–HCO_3 water type, with median U concentrations significantly elevated in Ca-HCO_3 and Mg-HCO_3 water types. The optimal cut-off points for hydrochemical parameters (pH, Eh, T, K, Na, Si, Cl, HCO3, TDS) are obtained by ROC analysis along with redox conditions and pH values as primary hydrochemical factors controlling the distribution of U in groundwater. Regarding the complexity of uranium geochemical cycle and various parameters that may be predictive for high U concentrations, logistic regression was applied including predictors with statistical significance. Evaluation of the univariate and multivariate statistical models suggested that the occurrence of elevated U in groundwater are related to (i) bedrock lithology, i.e. derived from weathering or dissolution of volcanic source aquifer materials, (ii) aquifers with oxidizing conditions and near neutral to alkaline pH values and (iii) water type.

Code of abstract: T8.3.2
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Use of isotopes in exploration of mineral and thermal waters – examples from Slovenia

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KEY WORDS mineral and thermal water, water and gas origin, monitoring, isotopes, geothermal energy

ABSTRACT
Mineral and thermal water resources in the Pannonian basin and its surroundings are an important economic benefit also in the eastern part of Slovenia. They have been used in spas and for bottling for decades, nowadays also as valuable natural features for tourism and for production of geothermal energy. Several completed EU, national and privately-financed projects, e.g. T-JAM, TRANSENERGY, ARRS programme Groundwaters and geochemistry, reporting for water concessions, investigation in Rogaška Slatina etc., interpreted the water and gas origin with various focuses of the research and therefore by using diverse methodologies and isotopes. The latest on-going EU project DARLINGe, which is supported by the Danube Transnational Program and covers also the territory of east Slovenia, will continue previous work in such way that the gained experiences will be used to plan the field and laboratory investigations in most successful manner to be able to outline and characterize large transboundary hydrothermal reservoirs which extend from Slovenia into the neighbouring countries.

Previous investigations were performed by several laboratories and in various scales, from local to regional ones. They show high applicability of standard hydrogeochemical approaches, for example of the use of stable isotopes of oxygen, hydrogen and carbon in water and activity of tritium, as expected. However, they also demonstrate that proper caution and consistency have to be taken to ensure sufficient quality of the results. More focused research have highlighted high usability of analyses of isotopes of boron and strontium, isotopes of sulphur and oxygen in sulphate, carbon isotopes in CO_2 gas, and chemical and isotope composition of noble gases, all in practice very rarely performed analyses. Moreover, a discussion on usability of carbon-14 dating in waters with evident dilution of carbonates was also initiated.

Previous projects showed good and poor practices in sampling and analyses of isotope composition of mineral and thermal waters. From these experiences, a sound working plan for hydrogeochemical characterisation of geothermal reservoirs within the DARLINGe project area will be elaborated to investigate the transboundary thermal groundwater flows in the most efficient manner.

Code of abstract: T8.3.3
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Natural Background Levels and geochemical anomalies in groundwater

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KEY WORDS - Natural Background Level, groundwater body, geochemical anomalies, spatial analysis, indicator kriging

ABSTRACT

The European Water Framework Directive (WFD 2000/60/CE) requires Member States to evaluate the status of groundwater bodies (GWBs). To assess the status of GWBs the evaluation of natural background levels (NBLs) for groundwater is commonly performed. The NBL is the concentration of a substance in GWB corresponding to no, or only very minor, anthropogenic alterations to undisturbed conditions (2006/118/EC).

NBLs in ground water can be calculated using different methods: currently, there are mainly three methodologies more used for NBL derivation. The first is the probability plots method (PP) and it is based on the separation of different populations of data by using statistical procedures; the second is the Pre-Selection method (PS), and it is based on the exclusion from the data set of the samples showing anthropogenic contamination, and after the NBL for each species is derived from a fixed percentile, generally 90th, of the probability distribution; the third is the Component Separation method (CS), and it is based on the assumption that the natural and the anthropogenic component are represented, respectively, by a lognormal and a normal distribution, detected as two peaks in the frequency distribution plots.

Being all these approaches statistically based, the consistency and the spatial distribution of the dataset are critical.

Under peculiar hydrogeological conditions, e.g. presence of tectonic structures, upwelling of hydrothermal fluids or interactions with sea water, the concentrations of certain elements in groundwater can locally increase, and determine natural geochemical anomalies inside a GWB. If the extension of these anomalies is small (e.g. the faults at the borders of an alluvial plain) compared to the GWB, the high values observed therein can be part of the upper tail of the dataset exceeding the 90th percentile and therefore excluded from the NBL calculation by the methods: in this case it may happen that groundwater of this mineralized area can be falsely interpreted as the results of contamination.

The deep knowledge of the hydrogeological setting, the use of spatial statistic including probability maps, can be decisive for distinguishing these hydrochemical anomalies within the GWBs and eventually apply different NBLs within the same GWB.

In this communication, selected case studies in which these conditions may lead to an incorrect evaluation of groundwater body status are described and analysed by means of spatial statistics and indicator kriging.

Code of abstract: T8.3.4
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Hydrogeochemistry of hotsprings in northwest Jiangxi Province, SE-China

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KEY WORDS - Hydrogeochemistry, Geothermometer, Hotspring, Isotopes, Mineral-fluid equilibrium

ABSTRACT
The hydrochemistry and isotopic composition of geothermal waters from the three geothermal fields, Bailing-Hotspring Area, Tangqiao-Hotspring Area and Jiuxiantang-Hotspring Area in the northwest of Jiangxi Province, SE-China, are systematically analyzed. Based on the hydrogeochemical and isotopic data, the mineral-fluid equilibria are simulated using PHREEQC program, and the mixing of cold groundwater with the geothermal water during its upward migration is evaluated by AQUACHEM program. The results showed that geothermal waters from all the three hot spring fields are of meteoric origin and their recharge elevation range from 850m to 1200m for Bailing Hotspring, from 830m to 1000m for Tangqiao Hotspring, and from 600m to 900m for Jiuxiantang Hotsprin respectively. According to tritium analysis, the age of hotsprings are 5-67a for Bailing Hotspring, 22-70a for Tangqiao Hotspring, and 4-26a for Jiuxiantang Hotspring respectively. The hydrochemical types of all the thermal waters are mainly HCO_3-Na and Na-HCO_3-SO_4. Water-mineral equilibrium studies suggest that all the three geothermal fields are departure from equilibrium, only a few minerals such as quartz, chalcedony and calcite convergent at a similar temperature. Various geochemical geothermometers calculation results show that the chalcedony geothermometer gives subsurface temperatures reflecting the real situation of deep geothermal reservoirs in the low-mid temperature geothermal systems of Jiangxi province. The chalcedony geothermometer gives subsurface temperature between 82～110℃ for Bailing area, 115℃ for Tangqiao area, and 73～85℃ for Jiuxiantang area respectively. Integrating the above results and the local conditions, all the three geothermal hot springs are suitable for direct use.

Code of abstract: T8.3.5
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

The study of rare earth elements migration in different hydrogeochemical environments

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KEY WORDS rare earth elements, hydrogeochemistry, migration, groundwater, Serbia

ABSTRACT
Systematically varying properties and generally coherent and predictable behavior of rare earth elements (REE) make them as potential tracers for studying water/rock interaction and weathering processes. Dissolved REE concentrations in 190 samples of groundwater of Serbia were analyzed with the goal of quantifying the natural REE variability and to discuss the controlling factors of REE concentrations. Quantitative challenges presented by multiply censored data were addressed with nonparametric statistical methods. The abundance of REE decreases with increasing atomic number, indicating that median concentrations of light REE are higher than those of the heavy REE. Nonparametric correlation analysis of REE and major solute chemistry components shows significant relationships between light and middle REE with Na, K, HCO_3. When regarding heavy REE moderate correlation was noticed only with HCO_3 which coincides with greater stability of HREE in alkaline groundwaters. It was observed that slightly acidic environment and redox processes contribute variations of REE concentration in the groundwater. When regarding migration of these elements in different hydrogeochemical environments, the best way to analyze multivariate REE data was using the plot of reference-normalized concentrations. Normalized pattern captures key features of REE profile and allows comparison between samples and depicts anomalously enriched or depleted elements. The results showed that anomalies of Ce and Eu and interelement ratios between groups of REE are good indicators of the geological source and the mechanisms controlling their migration in water. These new variables enabled making groups of samples that share similar hydrogeochemical properties and indicate the influence of different types of rocks on the genesis of a hydrochemical composition of groundwater.

Code of abstract: T8.3.6
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Migration of essential microelements in different types of mineral waters: Examples from Serbia

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KEY WORDS: microelements, mineral waters, multivariate statistical analysis, hydrogeochemical processes, spatial distribution

ABSTRACT
Physical and chemical characteristics of mineral waters on the territory of Serbia were examined in this study, in order to identify the main factors that influence the hydrogeochemical behavior of selected group of essential microelements. Over 130 mineral water samples were collected, from different types of aquifers (igneous, metamorphic and sedimentary rocks) and from different hydrogeological units. Temperature, pH and conductivity were measured on raw samples *in situ*, while major anions and cations, as well as microelements (F, B, Li, K, Sr and Si) were determined in the laboratory. Multivariate statistical methods (factor analysis, Q-mode cluster analysis and R-mode cluster analysis) have been applied to 110 mineral water samples, with the charge balance errors within ±5%. Factor analysis extracted three factors, which explain 67.4 % of the total variance in the analyzed dataset. R-mode cluster analysis confirmed these results. The interpretation of obtained factors has indicated that several hydrogeochemical processes are important for the migration of examined microelements. These are: the influence of highly mineralized, hydrochemically mature groundwaters; weathering of schists, granitoid intrusions and Tertiary volcanic rocks; cation exchange; dissolution of carbonate rocks; the effect of non-carbonated thermal waters on silicate minerals. The mechanism of these processes has been studied and validated on a certain number of representative examples of mineral waters. Hierarchical cluster analysis has identified four groups (clusters) and eight subgroups, representing different hydrochemical types of mineral waters, which can be regarded as a new approach to classification of Serbian mineral waters. The effect of above mentioned hydrogeochemical processes on each cluster, i.e. water type, has also been examined. Pattern of spatial distribution of studied microelements has been perceived, as well as the range of variation of their concentrations. Hydrogeochemical modeling has been applied on a group of chosen mineral water samples, in order to calculate the most probable ion species of the analyzed microelements. By systematizing the results of this study, the favorable hydrogeochemical conditions for migration of each of the six considered microelements were defined.

Code of abstract: T8.3.7
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Radium and Radon Mobilization by Deicing Salt Contamination of Groundwater

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KEY WORDS Deicing salt contamination, Radium, Radon

ABSTRACT
This study presents evidence for the increased mobilization of radium and radon in ground water caused by deicing salt contamination. The study site was a permeable asphalt parking lot at the University of Connecticut, Storrs campus. The parking lot is installed over highly disturbed glacial till and native sandy silt overburden. The bedrock beneath the overburden in the area is a gneiss and ranges in depth from about 2 to 5m. The depth to the water table in the overburden varies from 1 to 3m. A monitoring well network was installed in the overburden in the vicinity of the parking lot to monitoring for salt contamination of the groundwater. During the winter months the parking lot and surrounding paved areas received treatments of deicing salt prior to snowfall events. The permeable nature of the asphalt results in significant fluxes of salt impacting the shallow groundwater immediately following the melting of snow and ice and the development of saline plumes that migrate slowly downgradient. In March 2016 the wells were sampled for isotopes of radium and radon to evaluate whether high levels of sodium in the groundwater could cause the mobilization of radium by ion exchange and in turn impact radon migration. A plume of radium in the groundwater coincident with the salt plume was detected. A positive correlation ($r^2 = 0.92$) was obtained between dissolved sodium and isotopes of radium; a negative relationship was observed between specific conductance and dissolved radon. In two monitoring locations, concentrations of radium were detected that exceeded the USEPA MCL of 5 pCi/L. Concentrations of radon in the groundwater were found to be at a level that theoretically could generate gas concentrations in the vadose zone that exceed the USEPA indoor radon standard by orders of magnitude. Given these findings, it appears that salt contamination of groundwater could increase the potential for human exposure to these radioactive and carcinogenic elements. We are further researching the correlation of salt contamination with radium and radon at other overburden sites and at locations where bedrock wells have been impacted by deicing salt.

Code of abstract: T8.3.8
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Uranium, Nitrate and Fluoride in drinking water of the Karoo Uranium Province, South Africa

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KEY WORDS Uranium, Nitrate, Fluoride, Karoo Uranium Province, radioactive

ABSTRACT

The Karoo basin is a semi-desert natural region of South Africa, defined by its unique topography, geology, and climate. Geographically, it sprawls over 40% of South Africa's landmass, with an annual rainfall of between 50 mm and 350 mm. Geologically, the deposits of the Karoo Supergroup is exposed extensively across the country; it also hosts well-preserved mineral resources like coal, shale gas, as well as radioactive minerals such as uranium; and it is hence known as the Karoo Uranium Province. With a plan of expanding a nuclear energy in South Africa, there has been an increase of application for uranium mining/prospecting right licenses in the Karoo Uranium Province. The area is situated in the dry part of the country where groundwater is the sole supply for water needs. This study was conducted to understand the groundwater and the uranium concentration before any mining activity commences. A total of 128 samples are analysed of which 112 were collected from groundwater boreholes, 9 from springs and 8 extracted from groundwater database. Groundwater and spring water sampled in the area shows the presence of uranium and many other heavy metals beyond permissible limits. Uranium concentration ranges from 0 to 60µg/L, nitrate ranges from 0.01 to 578.36 mg/L and fluoride ranges from 0.06 to 4.69 mg/L. Even though it has not been studied how much each person is affected by the exposure to uranium, nitrate and fluoride in the area, a spatial map shows that the large portion of the area has the U concentrations highly above the permissible limit of 15µg/l. In addition, the radioactive element is carcinogenic; intake of uranium in such high quantities may lead to increased cancer risk, liver damage and kidney problems leading to renal failure. It can be concluded that the groundwater users are affected by fluoride in some part of the area. Dental fluorosis was observed during groundwater sampling amongst the groundwater users.

Code of abstract: T8.3.9
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Explaning the CO2 and mineral water journeys from the earth mantle to subsurface carbogaseous aquifers and springs

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KEY WORDS Carbo-gaseous aquifer, granites, CO2, hydrogeology, geochemistry

ABSTRACT

Thermo-mineral and carbo-gaseous (TMCG) systems have an important economic reputation particularly for sparkling water bottling.
We present a comprehensive research based on a mutidisciplinary approach (geology, hydrodynamics, geochemistry, isotopes, datations, etc.). Its converging results allow robustly conceptualizing the journey and behaviour of both CO2 and natural mineral water flows in the TMCG system of the Saint-Galmier (France) natural mineral water, located in a peri-alpine Oligocene graben. Previous studies highlight that, within the first hundreds of meters below surface, the weathered fractured layer of the granite aquifer constitutes the main aquifer. This aquifer is splited into several compartments bounded by impervious faults and covered by saprolite and sedimentary semi-permeable cover.
At a 10-15 km depth, crust thinning enhances the uplift of mantle CO2 (delta 13C known to be between -8 and -4 permil). Geothermometer data, isotopic data (C and O) and solubility modelling show that this gaseous CO2 rises up along the graben faults and then dissolves, at a depth of about 2.5 - 3 km, in last glacial d18O-labelled water (delta 18O < -9.5 permil). CO2 there fosters water-rock interactions. This resulting highly mineralized CO2-water (HMW) rises up and then encounters at least 2 types of fractures: some that allow the continuation of the rising-up of HMW with dissolved CO2 (delta 13C of about -6 permil, typical of mantle signature), and a few others whose geometrical properties permit degassing and then the rising-up of only gaseous CO2 inside them. 13C fractionation occurring during degassing relatively enriches the water and depletes the gaseous CO2. The 3D characterization of the granite aquifer allows to precisely locate, at its base (200-300 m deep), inflows of (i) HMW with dissolved CO2, and (ii) gaseous CO2-plumes. The latest dissolves with water from the granite aquifer (that is also rather old – more than 140 y). The boreholes sited in the various compartments of the granite aquifer tap mixings between HMW and water from the granite aquifer, locally enriched in CO2 by the plumes, according to the geometry of these compartments and the location of CO2-plumes and HMV occurrences.
These results are of high interest for the management of the carbo-gaseous hydrosystem.

Code of abstract: T8.3.10
Type of presentation: Oral presentation
Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Gas geochemistry studies in geothermal and mineral waters of Mugla (SW Turkey)

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KEY WORDS - helium; gas geochemistry; mantle helium; Mugla, Turkey; Western Anatolia

ABSTRACT

In this study, helium isotope and gas geochemistry data of the mineral and thermal waters of Mugla province, located in Western Anatolia, are evaluated. According to previous studies, the inland and coastal geothermal waters in the study area are associated with high angle dip-slip fault systems related to Late Alpine tectonics. To this end, a total of twenty-four locations were sampled including nine coastal hot springs (CHS), two coastal mineral springs (CMS), three mineral water wells (MWW), five mineral springs (MS), one hot spring (HS) and four geothermal wells (GW). Twelve locations were sampled for gas dissolved in water and twelve of them were sampled for free gas. Discharge temperatures and electrical conductivity values, respectively, varied as follows: 26-39 °C and 15,000-56,000 µS/cm for CHS, 18-21 °C and 22,600-31,300 µS/cm for CMS, 15-19 °C and 1070-1760 µS/cm for MWW, 14-19 °C and 1000-3700 µS/cm for MS, and 22-33 °C and 680-26,700 µS/cm for GW. Gases from the Yatağan and Kavaklidere regions are composed mainly of CO_2 with variable amounts of N_2, CH_4, O_2, Ar, CH_4, H_2, and He. On the contrary, gases from the Koycegiz and Dalaman region are composed mainly of N_2 with minor amounts of CO_2, Ar, O_2, CH_4, H_2 and He. Air corrected helium isotope ratios of the samples range from 0.004 to 1.43 Ra (where Ra is the present-day atmospheric $^3He/^4He$ ratio $1.39x10^{-6}$), the majority of them being above the crustal value (0.02-0.05 Ra), hence demonstrating the contribution of a mantle component. A two-component mixing model between mantle He and crustal He was used to calculate the mantle helium percentages which came out to be between 0.1 and 17%. Mantle He percentages are between 1.3 and 17% for coastal hot and mineral springs, between 0.3 and 7.3 % for inland hot and mineral springs, and between 0.1 and 3.8 % for inland mineral water and geothermal wells. There seems to be no obvious correlation between air-corrected $^3He/^4He$ ratios and discharge temperatures for coastal hot springs although for geothermal wells, the samples with high discharge temperatures display relatively higher air-corrected $^3He/^4He$ ratios. The $CO_2/^3He$ ratios in gas samples range from 0.05 to $97x10^9$. Half of these values are lower than the average ratio reported for the upper mantle ($2x10^9$). The highest ratio belongs to a mineral spring from Yatagan. This sample has the highest CO_2 concentration (96%) among other samples.

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Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Hydrogeochemical study of mud volcanoes in the Eastern Crimea

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KEY WORDS - mud volcanoes, Eastern Crimea, hydromineral resources

ABSTRACT
The Kerch peninsula is located in the east part of Crimea. The climate of the eastern part of the Crimea is arid. The amount of precipitation varies from 350 to 450 mm; the average annual temperature varies about 7,5°C. There are big problems with fresh water on the Kerch Peninsula, but several types of the mineral springs are most widely distributed. It is a region of active mud volcanism. There is clay diapirism there. The Kerch peninsula is a part of the Kerch-Taman province. Two mud volcano fields are well known in the north Kerch peninsula: Bulganak and Tarchan. The chemical composition of fluid of different mud volcanoes are not the same, because the root system of the volcanoes penetrates to varying depths. Laboratory studies have shown that usually the principal components of brines were the 4 major ions sodium (Na^+), chloride (Cl^-), bicarbonate (HCO_3^-), sometimes sulphate (SO_4^{2-}). Average mineralization is about 20 g/L. The brine of the Bulganak and Tarkhan volcanos contains some components (iodine, borax, bromine and others) that are beneficial to human health. The study of the brine, isotopic composition and material of the mud breccia provides very important information about the composition and genesis of the groundwater and deep-seated strata. The Kerch peninsula is the chief hydromineral region of the Crimea and contains vast deposits of curative mud, salt, mineral waters, small reserves of oil and gas. This material was collected during the field trip to the Kerch peninsula in summer 2013 – 2016.

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Topic: T8. Mineral and Geothermal Waters
Session: T8.3. Hydrogeochemistry of thermal and mineral waters

Flow system analysis of the Villány thermal karst area, Hungary

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KEY WORDS hydraulics, karst, thermal water, hydrogeochemistry

ABSTRACT
The outcropping Mesozoic carbonates and their subsurface continuation - covered by young sediments - in the adjacent basin basement form a thick (up to 1700 m) karst reservoir in the Villány region (South Hungary). Natural thermal water discharge occurs at the boundary of outcropping carbonates and adjacent sedimentary basin. These regional discharge areas are favourable sites for hypogenic cave development as well. Some caves are characterized here by phenomena related to thermal waters: tectonically controlled maze-like pattern, morphological features (spherical niches), and minerals (huntite, aragonite, calcite as cave popcorns). Some of the caves are even today connected to thermal waters. The thermal waters and the caves were hitherto investigated separately. However, all these phenomena belong to one single karst system and they can be evaluated only if their context is understood, i.e. if their common cause is revealed: the pattern of groundwater flow and its thermal and geochemical characteristics. The aims of the present study in the Villány thermal karst area are 1) to evaluate the groundwater flow system based on measured hydraulic data, 2) to characterize the geochemical composition of the waters, using natural tracers to identify different fluid components, and 3) to evaluate the cave forming processes.
As a first step, a hydraulic study was set up for the southern foreland of the Villány Hills, using the basic regional hydraulic methods of hydrogeology (Tóth 2009). During this study pressure-elevation profiles, hydraulic cross sections and tomographic fluid potential maps were created. As a result, basically North to South fluid flow direction was determined until (-815) m asl elevation. Based on the p(z) profiles close to the hydrostatic pressure conditions overwhelm. Geochemically the area of Harkány differ only from the karst waters in the area. The elevated chloride and sodium content of these waters may indicate the fluid contribution of the sedimentary basin. Also, the radionuclides show the highest concentration in the area of Harkány, which may indicate fluid mixing. The National Research, Development and Innovation Fund has provided financial support to the project under the grant agreement no. PD 116227.

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Genesis analysis of thermal and cold springs occurred within a small area based on isotopic and hydrochemical evidence: a case study in Arxan, northern China

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KEY WORDS: Mineral springs, Thermal springs, Hydrogeochemistry, genesis, Isotopes

ABSTRACT
In this work, the origins and the genesis of Arxan springs are discussed, which are well known for the occurring of both cold and thermal springs. The hydrogeochemistry and environmental isotope data are utilized to understand characteristics and origins of the springs, the reservoir temperature is calculated using mineral saturation indices and geothermometers. Arxan geothermal system involves 16 springs with outlet temperature ranging from 10.9℃ to 41℃ within a small area, which can be classified into two groups based on Piper diagram. The main water type of Group I is mostly HCO_3-Na-Ca, with outlet water temperature between 10.9 ℃and 12.9 ℃ and was classified as cold springs. The main water type of Group II is HCO_3-Na. The temperature is between 22 ℃ and 41 ℃， they are mixed type of mineral and thermal springs. Based on the isotopic analysis, the $\delta^{18}O$ and $\delta^{2}H$ data points of the Arxan springs are near the global meteoric water line, implying that the spring water is of meteoric origin. The aquifer where the samples of Group I occurring is the shallow cold aquifer of Jurassic system related to local groundwater with groundwater age younger than 10 years, and the springs rise from the weathering crust and fissure. While the samples of Group II occurs in a deep low-medium temperature geothermal system recharged by deeply circulating meteoric water. The springs rise from the deep basement faults in the form of hot fluid with the groundwater age over 60 years. Various outlet temperature of Group II is mainly caused by the different mixture radio of shallow cold water, the proportion is estimated to range from 55% to 80% in the Arxan thermal springs calculated by mass conservation of enthalpy and silica dioxide concentration. The circulation depth of the meteoric water is about 1440m. The estimated thermal reservoir temperature is between 50~70℃ according to calculations using chalcedony geothermometers and computation of saturation indices for different solid phases. According to the hydrogeochemical results and hydrogeological features of the study area, a conceptual flow model for circulation of meteoric water is given to describe the low-medium temperature geothermal system of the Arxan springs.

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Radon and uranium concentrations in the Dogo spa waters in Korea

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KEY WORDS Radon, uranium, measurement, concentration, reduce

ABSTRACT
The Dogo spa water is known to has hydrogen sulfide as high as 0.1 mg/L and to has high content of radon and uranium although the water temperature is relatively low compared with other spa waters of Korea. The water was overflowing at the beginning of the time but the water is pumping from boreholes to meet the increase of demand since 1980. At present 25 boreholes exist in the area and 10 boreholes are pumping the water. The amount of spa water used for bath in 2010 was 1,100-2000 m^3/d. DTW (depth to water table) of the boreholes varies from 5 to 40 m. The general geology of the area is composed of Precambrian schist and gneiss, Cretaceous biotite granite and micrographic granite in the ascending order. The area is located at center of the biotite granite and covered with alluvium. The spa waters have water temperature of 21.0-35.5℃, pH of 6.83-8.73, and EC of 274-640 μS/cm, respectively. Two times of radon and uranium contents measurements in spa waters from 8 boreholes were carried out. The first measurement of radon and uranium concentrations (2011.5) was found to be 25.2-290.8 Bq/L (median 70.7 Bq/L) and 0.31-25.7 μg/L (median 8.54 μg/L), respectively. The second measurement of radon and uranium concentrations (2016.8) was found to be 32.2-127.1 Bq/L (median 65.4 Bq/L) and 0.32-24.4 μg/L (median 12.05 μg/L), respectively. Little difference was observed in radon and uranium concentrations in spa water between two measurements possibly due to the amount of spa water pumped is nearly the same. Compared with the median radon and uranium values of 53.6 Bq/L, 0.79 μg/L in Cretaceous granite area, the radon concentration of the spa water is somewhat similar whereas the uranium value is high. There was no spa water exceeding 30 μg/L of World Health Organization (WHO) guideline whereas 3 spas from first measurement and 1 spa from second measurement found to be above 100 Bq/L of WHO guideline. Therefore, it is necessary to reduce the radon concentrations in the air of spa pools.

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The Genesis of the Thermal-mineral Waters of Ilidža near Sarajevo, Bosna i Hercegovina

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KEY WORDS aquifer, thermomineral water, genesis, sulphate, Ilidža

ABSTRACT:
The springs of thermo-mineral waters of Ilidža near Sarajevo appear on the transition of the central and inner Dinarides in the Bosnia and Herzegovina, at the overthrust front of the Bosninan flysch and the far southeastern part of Sarajevo-Zenica Tertiary basin. The genesis of the thermal-mineral waters of Ilidža is closely related with geological structure, structural-tectonic and hydrogeological characteristics of the terrain on the slopes of the Mount Igman and the southwestern part of Sarajevo field.

The wider area of Ilidža is made of layers of Palaeozoic (Carbon, Permian), Mezozoic (Triassic, Jurassic - Cretaceous, Upper Cretaceous) and Cenozoic (Miocene, Quaternary) age. Primary aquifer of thermo-mineral waters of Ilidža are Permian-Triassic sediments with gypsum and anhydrites and secondary aquifer of Triassic carbonates and alluvial deposits.

The temperature of the thermo-mineral waters is a result of the intensity of the interaction depth of infiltration of atmospheric water and geothermal gradient, the static pressure in the lenses of Permian-Triassic deposits and the dynamic factors of thermo-mineral waters moving and ascending through porous rocks over long distances under extremely high pressure.

The thermo-mineral waters are of atmospheric origin, and had no connections with atmospheric or surface waters after 1953. The age of thermo-mineral waters varies from 13.593 to 32.937. Thermo-mineral waters are formed in the upper Pleistocene, at the time of the colder climate within the epoch. Sulphates in thermo-mineral waters originate from Permian-Triassic evaporites (gyps-anhydrites) and H_2S most likely from sulphates reducing conditions. CO_2 and thermo-mineral waters are of different origin. CO_2 is produced by metamorphosis of carbonates in the deeper layers of the Earth's crust. Thermo-mineral waters of Ilidža are a mixture of two water types of different mineralization and temperature. Water mixing is not affected by daily climatic fluctuations and other superficial factors.

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Water quality of the Onyang hot spring water

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KEY WORDS hot spring water, borehole, pumping, concentration

ABSTRACT
The Onyang hot spring water, located in the central western part of Korea, is one of the well known hot spring waters. The spring water has a long history to its use as baths. The geology of the area is composed of Precambrian banded gneiss, Jurassic granites and Cretaceous microgranite. The spring waters show the Na-HCO_3 chemical type with the temperature ranging from 38.1 to 50.8°C, pH value between 7.8 and 9.0, and electrical conductivity ranging from 295 to 460 μS/cm. The spring water was overflowing at the time of developing but the increase of spa water demand caused drilling of boreholes since 1970. There are 38 boreholes having well depth ranging from 124 m to 303 m with an average well depth of 242 m. Pumping rate of the 25 boreholes in 2011 is reported in the range of from 2,000 to 4,000 m^3/d. Consequently, water level decline was reported and water quality degradation is expected. Depth to water table of the area was deepened in the range of 90 - 180 m in 2011. For the investigation of hydrochemical changes in spring waters of the area, we compared water quality of 24 spring waters in 2006 with those of 2016. The results revealed that there is no significant change was observed in water temperature and field measurements between 2006 and 2016. However, the content of silica and fluoride, believed to be one of the indicator of water rock interaction in granite rock aquifers, decreases as pumping time went on. Uranium and radon concentrations of the spring water was also decreased from 7.97 to 3.07 μg/L and from 39.5 to 30.2 Bq/L, respectively, indicating that the inflow of shallow depth groundwater was occurred to the area due to the decline of water table. Therefore, it is highly advisable to reduce pumping rate of spring water to preserve the water quality.

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Quality and utilization potential of Serbia's mineral water resources

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KEY WORDS: Serbia's lithosphere, mineral water, occurrences, quality, use

ABSTRACT
The diverse quality of Serbia's naturally-carbonated mineral water resources is a result of geologic, geochemical, hydrogeologic and geotemperature conditions under which they occur. Exploration has revealed that about 80% of these resources are found in carbonate rocks and fault zones of igneous-tectonic structures, and 20% in permeable strata of sedimentary rocks in fractured zones of largely impermeable, hard bedrocks. The total yield of all registered occurrences is about 180 l/s, of which only about 20% is actually used at present.

Nearly 99% of the mineral waters contain 0.25 to 2.5 g/l of carbon dioxide. The CO_2 concentrations of less than 20% of the occurrences are from 1.5 to 2.0 g/l – the range believed to be the best suited for bottling. In spa towns that offer balneotherapy, CO_2 concentrations are from 0.35 g/l (at Selters Banja[1]) to 1.6 – 1.7 g/l (Bujanovačka Banja and Vrnjačka Banja). The dominant anion is HCO_3^-, except in one case where it is SO_4^{2-}. The prevailing cation is generally Na^+, rarely $Ca^{2+}$and very seldom Mg^{2+}. It has been noted that wherever Ca^{2+} or Mg^{2+} is predominant, the water is cooler (9 to 30°C) and the level of total dissolved solids lower (0.49 – 3.5 g/l). It is obvious that the ultimate chemical composition is formed in the shallower parts of the lithosphere. Trace components useful for medicinal purposes include SiO_2, Fe, HBO_2, Sr, F, Li, Rn and H_2S. More than 90% of Serbia's mineral waters are also thermal and, as such, are used in balneotherapy. The conclusion of the study is that the energy potential of these water resources is underutilized, especially of those whose temperature is higher than 50°C (Sijarinska Banja, Kuršumlijska Banja and Lukovska Banja).

[1] In Serbian, *Banja* denotes a spa town.