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Rogaška Slatina, Slovenia

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5-7 October 2022, Rogaška Slatina, Slovenia

"Making groundwater in the Danube region visible"

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Content

2021-22 HENRY DARCY LECTURE

Hydrogeochemistry in the 21st century

Chen Zhu

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Chemical and isotopic processes occur in every segment of the hydrological cycle. Hydrogeochemistry—the subdiscipline that studies these processes—has seen a transformation from "witch's brew" into a credible science. In the last two decades, we have seen tremendous progress in four research areas: the use of isotopic and chemical tracers to quantify groundwater recharge and submarine groundwater discharge, the kinetics of chemical reactions in aquifers, the mineral-water interface's control of contaminant fate and transport, and microbial processes' effects on groundwater chemistry.

Going forward, achieving net-zero emissions requires hydrogeologists to play our roles in storing billions of tons of carbon dioxide (CO_2) in minerals, soils, and aquifers, securing Earth materials for the transition from fossil fuels to renewable energies, and protecting water quality from these activities and under a changing hydrologic cycle. Hydrogeochemistry is front and center in efforts to address many important issues related to these challenges. As the research progresses, we will likely see watershed-scale models that closely link hydrogeochemistry to atmospheric processes and biogeochemical cycles. Advances in data science and machine learning will help hydrogeochemistry play a bigger role in water resources management.

2021-22 Henry Darcy distinguished lecturer

Chen Zhu is a Professor of Earth and Atmospheric Sciences at Indiana University, USA. He is also an adjunct professor in the School of Public and Environmental Affairs and School of Public Health at Indiana University. He specializes in water's reactions with minerals and rocks. Zhu holds a Ph.D. from Johns Hopkins University, an MSc from the University of Toronto, a BS from the Chengdu College of Geology, and a postdoctoral fellowship at the Woods Hole Oceanographic Institution. Zhu was a Fulbright Scholar and the 2006 recipient of the John Hem Award from the (US) National Ground Water Association. Zhu has been elected a fellow of the American Association for the Advancement of Science, the Mineralogical Society of America, and the Geological Society of America. His book with Greg Anderson, Environmental Applications of Geochemical Modeling published by Cambridge University Press, is used as a textbook at universities around the world.

ABSTRACTS

Geodiversity of Groundwater in the Danube Basin: a brief approach in the first International Geodiversity Day

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Geodiversity is at the roots of biodiversity and human culture. Geodiversity represents, in short, all geological materials and resources, including rocks, structures, fossils, soils and groundwater, together with the landscape manifestations of the geological processes that created, formed, moved, and shaped them in the dynamic Earth, and their interactions with biodiversity and human activity and culture. This concept has applications to many scales, from global to local. It is recognized and dealt with by scientists that are responsible for their investigation and also by the public for their fruition, and managers. In a world more and more dependent on geological resources and processes, geoliteracy is increasing worldwide in the general population in part put forward by recognizing the values associated with Geodiversity, including the geoethical, economic, scientific, scenic, and cultural.

When Geodiversity is concerned, surface and underground landscapes, geological formations and structures, and fossil assemblages, for their visual spectacularity, drive most public and managers' attention. There is clear evidence that groundwater, an essential component in Geodiversity, and by itself possessing a striking high intrinsic diversity, is often disregarded, and must be promoted. This is our role as Hydrogeologists.

To commemorate the first International Geodiversity Day (UNESCO) this presentation takes the opportunity of the 5th IAH CEG Conference, being held in Rogaška Slatina from 5th to 7th of October 2022, to focus on the groundwater geodiversity from the Danube Basin, showing its importance in a selection of aspects, from the natural, the utilitarian, the health, the touristic, the cultural and education.

Key words:
Geodiversity, International Geodiversity Day, Groundwater, UNESCO, Danube Basin

Links:
https://www.geodiversityday.org/ (consulted 23th September 2022)

North Algerian geothermal reservoirs temperature estimation by geology and chemistry methods

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Characterized by a Mediterranean climate with medium rain fall 600 mm and low evaporation rates. The geothermal reservoirs are encountered in Triassic sandstones, Liassic carbonates and lower Cretaceous formations. The thermal waters chemical characteristics of highly mineralized Na-Cl water type representing the deep thermal waters. For a good study of geothermal reservoirs characteristic, a multidisciplinary approach was adopted, including geology, hydrochemistry and geothermometry (i.e. the Na^{+}-K^{+}, Na^{+}-Li^{+}, Li^{+}-$Mg2^{+}$, Na^{+}-K^{+}-$Ca2^{+}$-Mg^{2+}, quartz, chalcedony and $\delta^{18}O$ (SO_4^{2-}-H_2O)). More than sixty samples collected recently in 2019 with a temperature average between 24 °C and 94 °C. Chemical analysis of those thermal waters displays a certain degree of salinity with sodium-chloride type waters domination. The maximal geothermal reservoir temperature estimated using geothermometers is about 120 °C.

Key words:
North Algeria, geology, geothermal reservoirs, chemical geothermometers, geothermal waters

References:

Ait Ouali, A., Issaadi, A., Ayadi, A., Maizi, D., Ouali, S., Bouzidi, K., Imessad, K. 2020: Update of the most important Algerian geothermal provinces. Proceedings World Geothermal Congress 2020. Reykjavik, Iceland, April 26 – May 2.
Ait Ouali, A., Issaad, A., Maizi, D., Ayadi, A., Bouhadjar, A. 2019: Geothermal potential in the Ouarsenis-Biban-Kabylie (North Central Algeria) : hot spring catalogue. Arabian journal of geosciences. 12: 741. https://doi.org/10.1007/s12517-019-4945-4
Ait Ouali, A., Issaadi, A., Ayadi, A., Imessad, K. 2019: The role of geothermal waters in sustainable development application of main north center Algerian hot springs (Righa, Biban, Ksena). European journal of sustainable development, 8/4: 30-36. https://doi.org/10.14207/ejsd.2019.v8n4p30
Arnòrsson, S. 2000: Isotopic and chemical techniques in geothermal exploration, development and use. Sampling methods, data handling and interpretation. International Atomic Energy Agency, Vienna: 351 p.
Maouche, S., Abtout, A., Merabet, N-E., Aïfa, T. Lamali, A., Bouyahiaoui, B., Bougchiche, S., Ayache, M. 2013: Tectonic and hydrothermal activities in Debbagh, Guelma Basin, Eastern Algeria. Journal of geological research, 2013: article no. 409475. https://doi.org/10. 1155/2013/409475

Distribution of thermal plumes from open-loop systems in the municipality of Murska Sobota

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The use of shallow geothermal resources for heating and cooling buildings plays an important role in densely populated areas, as it could contribute to the reduction of greenhouse gas emissions (Bayer et al., 2019). To achieve sustainable and efficient use of shallow geothermal resources, it is important to understand the heat transfer in the geological environment of the planned geothermal system.

In the municipality of Murska Sobota, NE Slovenia, the use of shallow geothermal resources with open-loop systems has increased in recent years. This is related to the presence of a highly productive intergranular aquifer with an average groundwater temperature of 12 °C (ARSO, 2022). The spatial density of installed open-loop systems in the city center is very high, which raises the question of possible mutual interference between the systems. With the establishment of a monitoring network in December 2019, we installed 15 probes in the existing pumping and injection wells that will provide us with continuous data on groundwater temperature and water level fluctuations.

The main goal of the research is to create a numerical groundwater flow and heat transfer model for the selected area, which will allow us to evaluate the impact of the open-loop systems on the subsurface. The analysis of collected data suggests thermal interference between neighbouring wells, which could lead to a decrease in the efficiency of the installed open-loop systems in the future.

Key words:
open-loop system, heat transfer, thermal interference, numerical modelling

References:

ARSO, 2022. Groundwater arhive. http://vode.arso.gov.si/hidarhiv/pod_arhiv_tab.php (1. 3. 2022)

Bayer, P., Attard, G., Blum, P., Menberg, K. 2019: The geothermal potential of cities. Renewable and sustainable energy reviews, 106: 17-30. https://doi.org/10.1016/j.rser.2019.02.019

Hydrochemical indicators of groundwater flow in the area of "Čukaru Peki" Cu-Au underground mine in eastern Serbia

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The physical and chemical properties of groundwater, together with the groundwater levels regime and rock hydraulic properties, are often used to understand and conceptualize the hydrogeological system. Prediction of the influence of mining works on groundwater, and vice versa, is a challenge due to significantly altered groundwater flow patterns in the raw materials exploitation areas in relation to natural conditions. Therefore, multiple parameters are assessed and monitored before and during exploitation to properly characterize and quantify the system for assessing groundwater inflows-dewatering needs, environmental impacts, and water balance. In the present study, a set of 200 groundwater quality analyses are used to determine the main water types and delineate characteristic parameters for tracing the groundwater origin and flow in the area of the Čukaru Peki mine.

The "Čukaru Peki" is a world-class copper and gold deposit discovered in 2012 in the vicinity of the "Bor" mining complex in eastern Serbia. The deposit consists of two major zones, the Upper massive sulphide zone and the Lower porphyry zone, at the depths from 400 to more than 2300 m below ground surface. The ore bodies are hosted in the Upper Cretaceous (UC) andesite and volcanoclastic, overlain by the UC and Miocene age clastic cover, with multiple faults identified in the area. The exploitation began in 2021, following the development of the main ore access infrastructure (twin decline and two shafts). The groundwater samples were collected before commencement and during the exploitation. The samples from UC and Miocene clastic sediments are pH neutral, low mineralization, Ca^{2+}-HCO_3^- water. Samples from the volcanic rocks show considerable variations depending on the location and depth of sampling. Evolution in chemical composition from Ca^{2+}-Mg^{2+}-HCO_3^--SO_4^{2-} type in "fresh" andesite toward Na^+-SO_4^{2-}-HCO_3^- water in altered andesite is identified. Further analysis included the application of multivariant statistical methods (namely Hierarchical Cluster Analysis and Discriminant Analysis) to delineate characteristic parameters and grouping of the samples. Ultimately, distinguished parameters are used for determining the origin of groundwater collected from underground adits and shafts.

The research demonstrated the application of statistical methods to a set of groundwater quality parameters for tracing the origin of inflows into underground mining works.

Key words:
mine water, hydrogeology, multivariant statistics, groundwater inflow, water quality

References:

Kpegli, K.A.R., Alassane, A., van der Zee, S.E.A.T.M., Boukari, M., Mama, D., 2018: Development of a conceptual groundwater flow model using a combined hydrogeological, hydrochemical and isotopic approach: a case study from southern Benin. Journal of hydrology, 18: 50–67.

Velojić, M., Jelenkovic, R., Cvetkovic, V. 2020: Fluid evolution of the Čukaru Peki Cu-Au porphyry system (East Serbia) inferred from a fluid inclusion study. Geologia Croatica, 73/3: 197-209. https://doi.org/10.4154/gc.2020.14

Building the 2D water flow model in the unsaturated zone of Zagreb aquifer in order to quantify aquifer recharge from precipitation

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The Zagreb aquifer represents the only source of drinking water for the capital of Croatia and is a strategic groundwater resource within the Croatian Waters' Water Management Strategy. Since a decline in groundwater level has been observed in recent decades (Vujević and Posavec, 2018), it became important to investigate and understand all sources of aquifer recharge. In order to identify and quantify recharge from precipitation, a research polygon was established in the southern part of the Zagreb aquifer at Velika Gorica well field, consisting of a research shaft in the unsaturated zone and a meteorological station. The shaft is equipped with TDR probes and tensiometers that continuously measure soil water content, electrical conductivity and matric potential, and is therefore suitable for the study of precipitation infiltration processes in the unsaturated zone. The electrical resistivity tomography method was performed on the soil surface adjacent to the shaft to obtain the distribution of electrical resistivity values. The area of the unsaturated flow model is 3 m wide and 3 m deep and is divided in 14 layers according to geophysical survey results. Precipitation represents the model inflow, whereas evapotranspiration and water seepage at the bottom boundary represent the model outflow. The lateral model boundaries are presumed to be impermeable. Initial conditions, i.e., initial moisture content values in the model domain are obtained using a MoisturEC program (Terry et al., 2018). Finally, the parameters of the unsaturated zone, i.e., soil water retention curves will be obtained in model calibration process that adjusts sediment parameters in all layers of the model until numerical water contents match measured water contents. Numerical simulation of water flow in the unsaturated zone will be performed using the program HYDRUS 2D. Knowing the exact amount of aquifer recharge due to precipitation can improve the existing regional numerical groundwater flow models and thus contribute to sustainable water management.

Key words:
unsaturated flow model, research polygon, precipitation infiltration, groundwater recharge, Zagreb aquifer

References:

Terry, N., Day-Lewis, F. D., Werkema, D., Lane Jr, J. W. 2018: MoisturEC: A new R program for moisture content estimation from electrical conductivity data. Groundwater, 56/5: 823-831. https://doi.org/10.1111/gwat.12650

Vujević, M., Posavec, K. 2018: Identification of groundwater level decline in the Zagreb and Samobor-Zapresic aquifers since the sixties of the twentieth century. Rudarsko-geološko-naftni zbornik, 33/4: 55-64. https://doi.org/10.17794/rgn.2018.4.5

Groundwater and geothermal resources in South America: Chile and Colombia overview

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In Colombia the energy matrix is mainly based on hydroelectric power (around 70 %), which is highly vulnerable to climate variations, especially with the influence of the El Niño or La Niña phenomena. On the other hand, the country has a high geothermal potential (Alfaro et al., 2021) that may be used to generate baseload, renewable, and green energy. The first geothermal power plant in the country is using co-produced fluids from oil production and was inaugurated in 2021.

Geothermal resources can be partly related to groundwater resources, depending on their use. Although the country has abundant surface waters, several areas depend on groundwater for human consumption and economic activities. In Colombia the interested in groundwater was boosted by the publication of the "National Integrated Policy on Water Resource Management". Then, in 2014 the National Groundwater Program and Aquifer Environmental Management Plans Guidelines were published.

In Chile geothermal energy has experienced an increasing social and institutional interest. Since 2017 is operating the Cerro Pabellon geothermal power plant (81 MW) that produces a total of 600 GWh/y. In the last years several direct-use and geothermal heat pumps projects have been implemented enhancing the strong energy-water nexus. Aquifers are important heat reservoirs because groundwater flow is a powerful heat carrier, and they can play a key role in reducing energy dependence on fossil fuel.

The different projects implemented by CEGA show that shallow geothermal resources could be especially relevant in urban areas. In fact, more than 50 % of the world's population lives in urbanized areas and accounts for 67–76 % of global final energy consumption, whereas fossil fuels derived reach 71–76 % (Change, 2015). Thus, through different cooling and heating projects, CEGA demonstrated how geothermal energy can contribute significantly to energy needs, food production, and the achievement of decarbonization goals.

Key words:
Energy needs, Heat, Aquifers, Resource management

References:

Alfaro, C., Rueda-Gutiérrez, J. B., Casallas, Y., Rodríguez, G., Malo, J. 2021: Approach to the geothermal potential of Colombia. Geothermics, 96: article no. 102169. https://doi.org/10.1016/j.geothermics.2021.102169

Intergovernmental Panel on Climate Change. 2015: Climate change 2014 : Mitigation of Climate Change: Working Group III Contribution to the IPCC fifth assessment report. Cambridge University Press, Cambridge: 1435 p. https://doi.org/10.1017/CBO9781107415416

Emerging contaminants in the Ljubljana Basin: from monitoring to mitigation

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Emerging contaminants include a wide variety of newly created, newly detected or newly researched chemicals, often with highly mobile, persistent and bioactive characteristics with potentially detrimental consequences to living organisms which were not being considered for environmental monitoring until just recently (Sauvé and Desrosiers, 2014). The boDEREC-CE project (Board for detection and assessment of pharmaceutical drug residues in drinking water - capacity building for water management in Central Europe) joined researches and water managers from seven Central European countries, including Slovenia, to identify the emerging contaminants issue in their own regions and propose some possible directions to address it, focusing mainly on the PPCP group of chemicals – pharmaceuticals and personal care products. Project activities consisted of the state-of-the-art reviews, sampling campaigns in pilot areas, modelling and a research of mitigation options.

The Slovenian pilot action was the entire Quaternary Ljubljana Basin which provides the local population with several drinking water resources. The results of project activities built on previous research (Jamnik et al., 2009) and showed that low concentrations of emerging contaminants can be found in the water environments of the Ljubljana Basin with some differences in the number and concentrations of emerging contaminants in surface water, shallow and deep groundwater. The occurrence and persistence of emerging contaminants in the water environment of the wider Ljubljana area, in other parts of Europe and the rest of the worlds presents a future challenge for water quality assessment and management but the steps towards resolving it could and should start now.

Key words:
Emerging contaminants, PPCPs, Ljubljana Basin, water quality, boDEREC-CE

References:

Sauvé, S., Desrosiers, M. 2014: A review of what is an emerging contaminant. Chemistry Central Journal, 8: 15. https://doi.org/10.1186/1752-153X-8-15

Jamnik, B., Auersperger, P., Urbanc, J., Lah, K., Prestor, J. 2009: Pharmaceuticals as indicators of anthropogenic influence on the groundwater of Ljubljansko polje and Ljubljansko barje aquifers. Geologija, 52/2: 241-248. https://doi.org/10.5474/geologija.2009.024

Vulnerability assessment of the upper aquifer to pollution: statistics and sensitivity analysis – a case study of Slovenia

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This study was part of work package (WP 7) in the overall project HOVER promoted by ERA-NET GeoERA which deals with harmonized groundwater vulnerability to pollution assessment and mapping of the shallow upper aquifer at both pan-European scale and national scale. In this European project, led by the German Geological Survey (BGR), 16 geological surveys from 13 different countries were participating.

Two index methods were identified from a set of proposed approaches to evaluate the intrinsic groundwater vulnerability in Slovenia: DRASTIC methods at non-karstic areas, which cover more than half of the Slovenian territory (10,876 km^2) and the COP approach at parts of Slovenian territory with karstic features dominating groundwater flow (9,400 km^2). For the application of both methods a set of spatially distributed input data were required. Both maps were done at scale 1 : 250.000, with resolution at 100 x 100 meters.

To get a general overview of the vulnerability assessment made in Slovenia a GIS modelling was used to obtain the mean, median, minimum (Min), maximum (Max) values, the standard deviation (σ_v) and the variation coefficient (C_v) for each parameter and for both final vulnerability DRASTIC and COP indexes.

In order to establish the relationship between the vulnerability obtained and the parameters considered, a map single-parameter removal sensitivity analysis (Oke, 2020) was performed. The method can be easily applied to the DRASTIC expression (not valid for the COP method). Two parameters were calculated: the sensitivity index (S) for each parameter and the effective parameter weight (W). To complement the statistical analysis, pairwise correlations between the 7 parameters were calculated (Arno and Broda, 2021).

Key words:
vulnerability, groundwater, DRASTIC, COP, Slovenia, statistical and sensitivity analysis

References:

Oke, S. A. 2020: Regional aquifer vulnerability and pollution sensitivity analysis of drastic application to Dahomey Basin of Nigeria. International Journal of Environmental Research and Public Health, 17/7: article no. 2609.

Arno, G., Broda, S. 2021: Deliverable D.7-3 : results of the vulnerability assessment of the upper aquifer to pollution at pilot areas scale : statistics and sensitivity analysis, project Hover, GeoERA.Internet: https://geoera.eu/projects/hover8/ (1. 3. 2022)

Breaking the current recharge paradigm in Central Chile: a deep borehole for Andean groundwater flows estimation

Linda Daniele[1,2,3], Benoît Viguier[2,4], Matias Taucare[1,2,3], Daniele Tardani[2,4], Etienne Bresciani[5], Diego Morata[1,2,3]

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Ensuring water supply to the increasing world population, under the current climate change and droughts scenarios is one of the mayor's global concerns. The increasing requirement for water, food and energy plus the surficial water quality depletion and changing climate's impacts are resulting in increasing reliance on groundwater, representing by far the largest store of unfrozen freshwater on the Earth. Understanding the groundwater recharge process is crucial for an efficient and sustainable water resource management. Central Chile is suffering a severe long-term drought where recorded precipitation deficit is up to 40 % and surface water resource decrease may reach up to 90 %. As a direct consequence, the rising groundwater demand generated alarming water table withdrawals. Recent studies have highlighted the relevance of the mountain block recharge mechanism in delivering water to the alluvial aquifers downstream. So, in the Principal Cordillera, groundwater circulates through the complex network of faults and fractures cutting the volcano-sedimentary units of the Andes and reaches the Central Depression aquifers. To delineate the quality and sustainability of groundwater recharge in Central Chile, we have proposed a comprehensive hydrogeological study to acquire direct observations of the Andean groundwater flows.

The borehole drilled with diamantine, using a PQ size (diameter of 122.6 mm), allow us to use the core for detailed hydrogeological (i.e. permeability, porosity), structural (i.e. fractures, faults), petrography and mineralogical analysis. Tests performed during, and post drilling operation together with a continuous monitoring measures the changes and variation over time. We have set up the first and complete monitoring point of the groundwater recharge through a whole direct observation of sub-surficial and deep flows along the fractured zone of the Aconcagua Basin. Thus, through drilling a deep borehole (>450 m) we have improved the understanding of the processes governing the water cycle in Central Chile by focusing on their changing dynamics in connection with the rapidly changing human environment. Direct measurements on recharge will grant a better grasp of the Central Chile water resources and will promote a scientific-based management policy.

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Key words: *Drilling, Conceptual models, Groundwater monitoring*

The treated wastewater effluent impact on contamination of water supply aquifer during one decade of water exploitation (Tursko well field, Poland)

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The studied recharge zone of water supply aquifer (Tursko well-field, Poland) is located in an area of sparse water resources, where groundwater contamination was discovered, manifested by high nitrate concentrations and pharmaceuticals occurrence. The main objective of the study is documentation of steady deterioration of groundwater chemistry during one decade of groundwater exploitation and the trace of the wastewater impact on groundwater with use of pharmaceuticals as an anthropogenic tracer. This study presents an anthropogenic impact on groundwater chemistry caused by influence of treated wastewater and drainage water. These waters infiltrate into groundwater from losing drainage ditch located in the water supply aquifer's recharge zone. It was determined that strongly contaminated water could deliver organic matter and nutrients to groundwater, what is the factor activated/intensified denitrification. As a result, the nitrate concentration decreases in groundwater, but concentrations of denitrification products increase. The oxidation of organic matter overlaps and causes periodical exceeding of the upper permissible limits for drinking water. The investigation of treated wastewater impact on groundwater chemistry was supported by pharmaceuticals as an anthropogenic tracer, indicating that infiltration of wastewater is a significant factor that influences groundwater drinking-water quality.

Key words: *pharmaceuticals in groundwater, groundwater contamination by treated wastewater, denitrification, nitrate pollution*

Monitoring and analysis of groundwater regime at the sources of the Novi Sad water supply system

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Today's water supply system of the city of Novi Sad has three groundwater sources (Strand, Petrovaradinska ada and Ratno ostrvo), which operates 21 wells with horizontal drains and 15 vertical wells. Due to the decrease in the capacity of the watersource, as a consequence of the aging of the wells, the capacity of wells was reduced compared to the initial one, after construction. In order to regularly maintain the wells and the watersource as a whole, well regenerations were carried out which gave the desired effects and the yield increased compared to the previous situation. In order to overcome this problem, JKP "Vodovod i kanalizacija" -Novi Sad in cooperation with the companies "Beogeoaqua" d.o.o. and "PST Bohr" d.o.o. started the rehabilitation of wells with horizontal drains by the "Fehlman" method, which increased the capacity of the watersources "Petrovaradinska ada" and "Ratno ostrvo". The wells at the "Petrovaradinska ada" source have been completely rehabilitated, and the capacity of the watersource has been increased from 250-270 l/s to 600-650 l/s. As the capacity increased by more than 2 times compared to the situation before the well regeneration, it means that the injection of new drains had a full effect, ie the initial yield of the well was restored. With proper management and operation of the watersource, as well as its regular maintenance, the wells have maintained a stable capacity as a function of time, as evidenced by ten years of regular monitoring of the exploitation regime and groundwater levels of the watersource "Petrovaradinska ada", where a stable regime of wells for the period under consideration. The "Ratno ostrvo" watersource is in the process of well regeneration, and currently 3 wells (BHD-5, BHD-6 and BHD-8) out of the existing 9 have been rehabilitated by insering new drains. Capacities before the well regeneration were 20-50 l/s (BHD-5 and BHD-6), so that the injection of new drains by the "Fehlman" method has increased the capacity of the wells by 110 % (BHD-5), 67 % (BHD-6) and 195 % (BHD-8).

Key words:
Ranney wells, groundwater regime, watersource, water supply

References:

Tehcnical reports on well regeneration of watersources "Petrovaradinska ada" and "Ratno ostrvo" in the period 2009-2022, Beogeoaqua

Hydrogeology of a populated alpine research area affected by a creeping landslide in Sibratsgfäll, Austria

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Austrian alps are characterised by high geographical reliefs and precipitation rates that often exceed 2000 mm/year. Recent studies have shown that especially alpine regions are highly sensitive to climate change with a predicted temperature rise of more than twice of the global mean. The objective of this study is to improve the understanding of hydrogeological processes of inneralpine catchments on a case study level considering events of heavy rainfall and droughts, past climate reconstruction (1995-2020) and future climate models (until 2100). The 5 km² site is situated in Sibratsgfäll, Vorarlberg, Austria at an altitude between 800-1.400 m asl. and is affected by slope creep (3-11.5 cm/year). Emphasis is given to the development of a conceptual hydrogeological system taking account of the water balance, infiltration pathways, groundwater residence times and extreme climatological effects. The yearly precipitation within the project duration sums up to 2600 mm/year and approx. 50 % discharges via the surface and via lateral shallow (< 10 m depth) subsurface flowpaths. Evapotranspiration is estimated with max. 30 %, and approximately 20 % of precipitating water infiltrates into the ground. Precipitation in the Flysch dominated area at higher altitudes is transported slope parallel in the upper part of the glaciolacustrine sediments. The Mean Residence Time of the groundwater from artesian wells found in glacial coarse-grained deposits below silt/sand dominated glaciolacustrine sediments in the western part is older than 30 years. 3D and numeric modelling describe variations and trends in groundwater storage of this unit under consideration of downscaled regional climate model runs. Those are based on the three greenhouse gas concentration scenarios RCP2.6 (relatively low), 4.5 (intermediate) and 8.5 (very high). Significant trends until the end of the 21st century emerge for RPC8.5, where also events of summer drought and heavy precipitation-snowmelt are projected to intensify.

Key words: *Alpine, hydrogeology, landslide, groundwater storage, climate change*

Open learning online school: a knowledge-sharing tool about geothermal and groundwater resources

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The UNESCO IGCP636 project is dedicated to promote the use of geothermal resources for energy transition through 1) improving the understanding of groundwater flow, heat and mass transfer in fractured and porous media, fluid-rock interactions, rock fissuring, and reactivation of existing faults; 2) fostering the development of medium-low enthalpy geothermal energy extraction systems; 3) promoting outreach, training, and educational activities about geoscience and geothermal resources as renewable, clean, and base-load energy (IGCP636, 2021).

Among the 17 Sustainable Development Goals (SDG) of the 2030 Agenda, the targets of SDG 7, which focuses on the access to affordable, reliable, sustainable, and modern energy (UNDP, 2018), define the background of IGCP636 project.

To share knowledge about geothermal resources, the "Geotheroom" activity was created as an open access international virtual school, hosted by the online learning platform supported by Universidad de Medellin (Colombia).

The project was launched in February 2022, starting with Colombia as the host country of the IGCP636 project, and it is expected to end in November 2022 with Italy. Other countries included in the school are Mexico, Iceland, Algeria, Sweden, France, Canada, Spain, and Slovenia. Each month, information about the current geothermal development is shared through the platform and national experts are invited to panels/talks to conclude the analysis of the country.

The experience with Geotheroom as a platform for dissemination in geosciences and the connection between scientists and students has been successful, opening a door for this type of project to go beyond and not only focus on geothermal energy, but also on hydrogeology and other related topics. It is an opportunity to expand the project's reach among different fields in the geoscientific, environmental, and energetic community. In this case, the Geotheroom experience could be extrapolated to hydrogeology, applying the same methodology.

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Key words:
education, geothermal, online course, international geoscience programme, outreach

References:

IGCP636, 2021: Geothermal resources for energy transition. https://igcp636.com (1. 6. 2022)
UNDP, 2018: The 2030 Agenda in action. What does it mean? United Nations Development Programme, New York, 9 p.

Higher spatial resolution of groundwater levels in the Lower Savinja River Valley, Slovenia, in period 2020 - 2021

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Slovenian Environment Agency (ARSO) has a primary monitoring network of 14 sites in the alluvial aquifers of the Lower Savinja Valley on an area of approximately 100 km^2. On average, every monitoring station covers 7 km^2 of territory. The network is set up for monitoring groundwater parameters and assessing groundwater quantitative status. The primary national monitoring network ensures continuous, long term, and reliable measurements of groundwater levels, temperature, and electrical conductivity.

To understand the local characteristics of the aquifer, the primary network density is too loose, therefore; the extended, secondary network is occasionally established. The purpose of the secondary network is more detailed monitoring of groundwater levels. Together with the primary network it provides a denser network of measurements for more accurate determination of the aquifer characteristics. In years 2020 and 2021, in addition to the primary monitoring network, measurements at additional 28 sites were carried out to provide more detailed information on groundwater level fluctuations in the observed area. The secondary monitoring network was equipped with data loggers for groundwater level and temperature measurements. The quality and continuity of the data were ensured by regular one to two months in-situ observations, transmissions, and data checks. During the monitoring period, there were a total of 42 measurement sites in the investigated area, which means, on average, one measuring site per 2.5 km^2.

We will present the main results based on denser research measurements in the Lower Savinja Valley. Measured groundwater levels will be used to create groundwater level maps at various temporal levels within the period of the measurements. This will improve the knowledge of the aquifer characteristics and provide additional information on the groundwater flow direction and seasonal level fluctuations.

Key words: *groundwater, alluvial aquifer, groundwater level measurements, monitoring network*

Why Geothermal? Analysis of Community Acceptance to Promote Energy Justice and Sustainable Development Strategies in Rural Argentina

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As greenhouse gases continue to rise, demand is increasing for meaningful and workable solutions to combat climate change. Many countries are broadening their energy matrix and exploring opportunities to develop Geothermal Power Projects (GPPs), often in regions where industrialization has not occurred (Popovski, 2003). As the number of GPPs in pre-feasibility grows, it is imperative that the development of these projects is done in a socially just and equitable manner. Decision-makers should act early in the planning of renewable energy ventures to adequately inform the public of risks and benefits (Karytsas and Polyzou, 2021).

This research investigates community acceptance and understanding of geothermal energy amongst the people of Varvarco, a small, remote village in the Argentinean Andes. Varvarco is the closest settlement to Argentina's highest potential geothermal project, Domuyo. Through a series of one-on-one interviews, internet surveys, and discussions, the theory is tested that education and encouraging interest can improve public opinion of geothermal technologies among marginalized populations. Based on qualitative data gathered from this study I suggest a variety of direct-use projects to continue to enhance public perception of geothermal energy. The results of this study are discussed in the context of energy justice in developing economies and which sustainable development goals can be championed in Varvarco.

By opening a dialogue with local stakeholders and embracing their concerns developers can build trust (Dewhurst, 2014). When local needs are actively incorporated into design solutions, the result can be impactful and balanced GPPs. Ignoring the traditions of the people who have lived for generations in zones that policymakers recently set aside for renewable energy enterprises has led to social resistance movements (Santoso and Kusumasari, 2019). When contractors work alongside communities early in project planning, site-specific and circular designs can be integrated into the daily lives of the population most affected by the rush to carbon neutrality (Barich et al., 2021).

Key words:
community engagement, social acceptance, geothermal, sustainable development, energy justice

References:

Barich, A., Stoklosa, A. W., Hildebrand, J., Elíasson, O., Medgyes, T., Quinonez, G., Casillas, A. C., & Fernandez, I. 2021: Social license to operate in geothermal energy. Energies, 15/1: 139. https://doi.org/10.3390/en15010139

Dewhurst, K. 2014. Social and Political Consequences of Geothermal: A Case Study From the Nereidas Valley, Nevado del Ruiz, Colombia. GRC Transaction, 38: 847–850. https://publications.mygeoenergynow.org/grc/1033631.pdf (1. 6. 2022)

Karytsas, S., & Polyzou, O. 2021: Social acceptance of geothermal power plants. In: Colpan, C. O., Ezan, M. A. & Kizilkan, O. (eds.): Thermodynamic analysis and optimization of geothermal power plants. Elesevier, Amsterdam: 65–79. https://doi.org/10.1016/B978-0-12-821037-6.00004-4

Popovski, K. 2003: Political and public acceptance of geothermal energy. The United Nations University - Geothermal Training Programme. https://rafhladan.is/bitstream/handle/10802/4807/UNU-GTP-2003-01-03.pdf?sequence=1 (1. 6. 2022)

Santoso, P. F. & Kusumasari, B. 2019: Key Elements of Environmental Justice in the Geothermal Power Plant Resistance Movement. Jurnal Politik, 5/1: 65. https://doi.org/10.7454/jp.v5i1.207

Optimization of well field management to mitigate groundwater contamination in Brest Water Works (Central Slovenia)

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The Brest Water Works has been part of the public drinking water supply system since 1987 and provides about 10 % of the drinking water for the city of Ljubljana and its surroundings. This study presents the optimization of well field management design to reduce desethylatrazine (DEA) concentration in deep wells of the Brest Water Works (Janža, 2022). The high DEA concentration in groundwater has limited the pumping rate from the deep wells and reduced the delivered water quantity for the drinking water supply system. The artificial recharge of groundwater through injection wells was investigated. The goal of the proposed intervention is to alter the groundwater flow pattern and direct the contamination plume away from the production wells.

A multi-objective simulation-optimization framework was developed. A transient groundwater flow and solute transport model was used to simulate the effects of various artificial groundwater recharge and pumping regimes. It was coupled with the shuffled complex evolution method to identify optimal well field management designs.

The results showed that optimized well field management designs can significantly reduce DEA concentration in production wells, assure compliance with water quality standards with reduced injection rate, and, with the implementation of two injection wells, achieve lower DEA concentration and higher pumping rate. The optimization solutions depend on the defined well field management priorities and reveal a trade-off between the objectives (reduction of DEA concentration, increase of pumping rate, and reduction of injection rate). The impact of management variables on mitigation efficiency is not uniform and largely depends on the location of the injection well(s), which increases the complexity of mitigation design.

Key words:
groundwater management, drinking water resource, artificial recharge, multi-objective optimization, shuffled complex evolution method

References:

Janža, M. 2022: Optimization of well field management to mitigate groundwater contamination using a simulation model and evolutionary algorithm. Science of the total environment, 807/1: article no.: 150811. https://doi.org/10.1016/j.scitotenv.2021.150811

Hydromorphological analysis of the Vipava River along the infiltration interval near Miren

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As part of our research, we study the impact of infiltration of a non-karst watercourse on the water balance of a karst aquifer. The research is taking place in the area where the Vipava River and the Classical Karst aquifer come into contact in the lower Vipava Valley.

The amount of water inflow into the Karst aquifer is determined by comparing the measured flows in successive sections in the Vipava River. In order to list the characteristics and physical properties of the riverbed and riverbanks, field mapping of the hydromorphological properties of the Vipava River between the towns of Bilje and Miren was carried out in parallel with the first flow measurements.

In the following, we present the main findings on the considered section of the Vipava River. The river bed is mostly natural, between 20 and 35 m wide, and in some places even more. The river flow is smooth and barely noticeable, the water is turbid, up to 5 m deep. There are frequent fallen trees and branches in the river. The river banks are also mostly natural, except at the end, where the left bank is reinforced with a rock armour. The banks are extensively overgrown with trees and bushes and are difficult to access, but in certain places they have been partially or completely cleared due to human activity. At the beginning of the section, the height of the right bank is higher than the left; the right bank reaches a height of up to 8 m, and the left up to 4.5 m. Further on, the two banks are mostly of the same height, around 3 m. The profiles of both banks are vertical or steep (> 45°). River withdrawals and storm water inflows are visible in the area. We also record one small permanent left tributary.

Key words: *Hydromorphological analysis, Vipava River, lower Vipava Valley*

Nitrate transport modelling in the Varaždin alluvial aquifer

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The Varaždin alluvial aquifer is located in the Drava River valley in NW Croatia, providing drinking water for approximately 170,000 inhabitants of the Varaždin County. In the last decades, this important water resource has become contaminated with nitrate above threshold limit of 50 mg/L. Within this work, nitrate transport is modelled in the area upstream of the Varaždin City, which is predominantly under agricultural activities. The future evolution of nitrate concentrations is predicted for scenarios that differ from each other in nitrate input from different land use classes. The modelling results indicated longer mean residence time in deeper parts of the aquifer (MRT>10 years), allowing slow progradation of contamination plume towards the main wellfield Bartolovec located downstream of the study area. The scenario analysis demonstrated that groundwater contamination with nitrate occurs mainly from agricultural sources, so the management of the agricultural practices seems to be of critical importance towards the remediation of the groundwater quality in the Varaždin aquifer.

Key words: *nitrate, transport, numerical modelling, Varaždin aquifer, Croatia*

The geothermal potential of Guelma region, East of Algeria

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Geothermal resources in Algeria are characterized by a high concentration of hot springs in the north east of the country. More than 282 thermal springs were inventoried in the North of Algeria with temperatures ranging between 30° and 96 °C. This zone being characterized by an important geothermal gradient of 5 °C/100 m.

The investigated area (Guelma, Algeria) is located in the north-east of Algeria and characterized by a semi-arid to sub-humid climate. This region is part of the external domain of the Maghrebian chain in eastern Algeria. The soils and subsoil are varied and range in age from Triassic to Quaternary. 13 samples of hydrothermal springs were analyzed using various techniques in order to assess their physico-chemical quality, the origin of the dissolved constituents of the thermal waters as well as the estimation the temperature's reservoir of the associated geothermal fields.

The spring waters were classified as low, moderate and high salinity. Mineral saturation indices (SI) calculated from major ions indicate that the spring waters are supersaturated with the majority of carbonate minerals while all spring water samples are under-saturated with evaporite minerals. The thermal spring waters have a meteoric origin and all samples are immature with a strong mixture between warm and shallow waters. The temperatures of the reservoirs to which the thermal waters relate are estimated to vary between 104 °C and 195 °C. The deep circulation of meteoric waters for the investigated area is fed by the high geothermal gradient around 5 °C/100 m and reaches a high temperature before rising to the surface. The reservoir estimated depths ranged from 2500 to 3000 m.

Key words:
Guelma, geology, geothermal potential, chemical geothermometers, hydrochemistry

References:

Ait Ouali A., Issaadi A., Ayadi A., Maizi D., Ouali S., Bouzidi K., Imessad, K. 2020: Update of the most important algerian geothermal provinces. In: Proceedings World Geothermal Congress 2020. Reykjavik, Iceland, April 26 – May 2.

Bouaicha, F., Hénia, D., Lazhar, B. et al. 2017: Hydrogeochemistry and geothermometry of thermal springs from the Guelma region, Algeria. Journal of the Geological Society of India, 90: 226–232. https://doi.org/10.1007/s12594-017-0703-y

Bouaicha, F., Dib, H., Bouteraa, O. et al. 2019: Geochemical assessment, mixing behavior and environmental impact of thermal waters in the Guelma geothermal system, Algeria. Acta Geochimica, 38: 683–702. https://doi.org/10.1007/s11631-019-00324-2

Arnòrsson, S. 2000: Isotopic and chemical techniques in geothermal exploration, development and use. Sampling methods, data handling and interpretation. International Atomic Energy Agency, Vienna: 351 p.

Maouche, S., Abtout, A., Merabet, N-E., Aïfa, T. Lamali, A., Bouyahiaoui, B., Bougchiche, S., Ayache, M. 2013: Tectonic and hydrothermal activities in Debbagh, Guelma. Journal of Geological Research, 2013: article no. 409475. https://doi.org/10.1155/2013/409475

The use of groundwater modeling to design in-situ remediation schemes

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In aquifer regions which show low oxygen concentrations in groundwater iron and manganese content dissolved in groundwater might increase when sources for these metals are existing. Thus, if concentration thresholds for drinking water use are exceeded groundwater treatment is needed. In situ remediation of iron and manganese has been successfully applied in the last decades either by injecting oxygen directly in the subsurface or by infiltrating oxygen enriched water which both initiate the building of an oxidation zone.

Groundwater models can be operated to facilitate the design of such a remediation arrangement. Pollutant transport modelling yields the distribution of groundwater oxygen concentrations that results from the mixing between regional groundwater conditions and the local remediation measures. In that context, the location of injection wells and the infiltration rate of oxygen in combination with a pumping scheme are optimized by groundwater model simulations to reach remediation goals. The corresponding geochemical processes can be considered by external calculations or by coupling a geochemical to the groundwater model.

We will show the coupled application of FEFLOW and PHREEQc to design the intermitting operation of two wells for groundwater withdrawal and reinjecting of oxygen enriched groundwater in the downstream area of a gravel pit in the Lower Mur Valley, which was shut down long ago. In general, such a coupling approach can be used to understand the occurrence of a wide range of compounds detected in groundwater if corresponding reaction parameters are available.

Key words: *in-situ remediation, groundwater modelling, FEFLOW, PHREEQ, iron, manganese, infiltration of oxygen*

Review of the karst water level monitoring wells in the Transdanubian Medium Mountains

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Within the framework of the present project, 217 wells of the karst water monitoring system, situated in the Transdanubian Medium Mountains, were examined on the basis of the structure- and hydraulic aspects. The starting point of the investigation is a major problem on the regional level - the regeneration of the karst system following a period of excess production (1960-1989), leading to rising karst water levels.

First, the main purpose of the study entailed an examination, aiming to prove whether the condition of the studied wells allows us to make further measurements of the water. Secondly, it aimed to examine the extent of the reliability of the data collected by the General Directorate of Water Management. The research embodied the determination of the exact location of the wells, the assessment of their condition, the measurement of the downhole equipment with a vehicle (natural gamma, temperature, hole width, continuous temperature profiling, ring space inspection, potential coloured video recording), along with the exploration of the well hydraulics (well capacity and backfilling, production continuous temperature profiling, differential temperature profiling, flow/swallow flow measurement).

During this project, unforeseen problems have arisen concerning the accessibility and the measurement process of the wells, which made the work even more fascinating and compelling. Approximately 85 % of the wells were measured, with only 70 % of which had the adequate depth for proper examination, due to their condition. In terms of their depth, the smallest well was 9.5 meters deep, while the deepest well was around 970 meters deep. In the case of most of the wells, there were obstacles that might have affected the course of the measurement and presumably might have affected the measurement of the extent of change in water levels.

Among the wells observed, some were in a markedly good condition in terms of their operation and the measurability of their water levels. Nonetheless, in some cases, the contrary was found to be true.

Key words: *monitoring well, karst water level, measurement*

Using stable isotopes to identify groundwater flow regime in Urbas landslide area (NW Slovenia)

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The hydrological and hydrogeological characteristics of the landslide area have an important influence on slope stability. The study represents an investigation of the Urbas landslide recharge area. The Urbas landslide is located in the Potoška planina area in NW Slovenia, in the Karavanke mountain range on the southern slopes of the Belščica Vajnež and Potoški Stol peaks and poses a high risk to the downstream settlement od Koroška Bela.

To characterize the groundwater flow regime in the study area and to plan landslide remediation measures analysis of major ions and stable isotopes $\delta^{18}O$ and $\delta^{2}H$ were used.

The groundwater is characterized as Ca^{2+}-HCO_3^- water type, indicating low water-rock interaction in a landslide area composed of Upper Carboniferous and Permian clastic rocks, and points to upper laying carbonate rocks and scree deposits as the main recharge area. This confirms the estimated average recharge altitude of the springs at the Urbas landslide which ranges from approximately 1,700 to 1,800 m a.s.l., with mean residence times ranging from 2 to 5 months (Koren et al., 2022). The study demonstrated that the presented combination of methods can be an effective tool for evaluating hydrogeologic processes in a difficult-to access terrain where the performance of hydrogeologic field investigation methods is limited.

Key words:
landslide, groundwater, stable isotopes, oxygen-18, deuterium, hydrogeology, recharge dynamic

References:

Koren, K. Serianz, L., Janža, M., 2022: Characterizing the groundwater flow regime in a landslide recharge area using stable isotopes, case study Urbas landslide (NW Slovenia). Water, 14/6: article no. 912. http://doi.org/10.3390/w14060912

A combined stochastic-analytical approach to the prediction of climate change impact on spring discharge

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A novel combined stochastic-analytical approach has been developed for the prediction of spring discharge time series based on regional climate model projections. This approach integrates the advantages of traditional stochastic methods with physics-based analytical baseflow models.

While hydrograph peaks (flood) originate from direct recharge into the aquifer, baseflow originates from the release of water from the low permeability rock matrix. For this reason, it is not possible to adequately describe these two different physical processes with one regression function. While flood peaks can be approximated by regression functions, baseflow requires the application of physics-based analytical functions.

The combined modelling method involved regression analysis between rainfall and discharge peaks. Baseflow was simulated using 2D analytical solutions (Kovács, 2003; Kovács et al., 2005), where fitting parameters were calibrated based on historical rainfall and discharge data.

A combined stochastic-analytical modelling of the Bijela spring flows (Durmitor area, Montenegro) was undertaken using RCP4.5 and RCP8.5 scenarios of the EURO-CORDEX climate model ensemble. The applied model scenarios predicted the probability and magnitude of discharge which were represented through Flow Duration Curves.

Key words:
karst, spring discharge, climate change, modelling

References:

Kovács, A. 2003: Geometry and hydraulic parameters of karst aquifers: A hydrodynamic modelling approach. PhD thesis, University of Neuchatel: 131 p.

Kovács, A., Perrochet, P, Király, L. & Jeannin, P-Y. 2005: A quantitative method for the characterization of karst aquifers based on spring hydrograph analysis. Journal of Hydrology, 303: 152-164.

Soil water origin and dynamics in sloped vineyard, SUPREHILL project

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The diversity of processes which take place in hillslope agro-ecosystems makes the estimation of vadose zone hydrology very challenging. This research presents first results related to the measurements of meteorological data, soil water content, granulometric composition and isotopic signature of soil water and precipitation within SUPREHILL project. Vadose zone observatory has been placed on agricultural sloped area in Zagreb, within experimental field Jazbina. For the evaluation of soil water origin and dynamics, precipitation and soil water have been sampled. First four sampling campaigns have been done in two week intervals, while after it was decided to start sampling on a monthly time period. Stable isotopes of hydrogen ($\delta^{2}H$) and oxygen ($\delta^{18}O$) from soil water and precipitation have been determined by laser spectroscopy. First results showed different isotopic signature in soil water compared to precipitation which suggests the existence of different infiltration patterns in the experimental site. Isotopic signature corresponds to the variation of water content at different depths. Furthermore, results suggest that preferential flow and infiltration of precipitation can be expected till the maximum depth of 0.8 m which is probably related to the existence of low permeable layer. Future research and long-term monitoring will focus on the quantification of subsurface soil water dynamics and preferential flow, as well as on the non-linear agrochemical transport processes.

Key words: *soil water, precipitation, stable isotopes of water, infiltration, hillslope vineyard*

Hydrodynamic and heat transport model analysis of the South-East Hungary in the aspects of energy and pore space utilization

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The objective of the study was to model the relevant flow and heat transport processes in the SE-Alföld (Hungary) region, considering the hydrodynamic properties of the basin sediments linked to high regional flow, the specificities of the basin formations and the heat recovery potential. Regional scale hydrodynamic and heat transport modelling was carried out using the finite element method in FEFLOW® modelling software. Subsequently, a fictitious high enthalpy heat recovery (doublet) case was simulated in a subarea (Pitvaros) using a high grid density embedded reservoir model. A model-series of a hydrothermal rather isolated system in 27 scenarios was executed.

The distribution of the extracted heat values through variations of hydraulic conductivity and value of water production compared to the volumetric reserve calculation using the UNFC-2009 method

Beside for the production to be protected, to predict the negative effects of pore space utilization on each other of existing and future utilizations also a useful tool is the geothermal protection zone delineation. The Peclet number obtained as an output from simulation studies provides a good indication of the area involved in the recharge and can thus complement the geothermal protective boundary definition. As illustrated by the model simulation series, geothermal investments of basement rocks carry a high economic risk if there is no indirect knowledge of a fracture system with natural permeability that the planned system can connect to. The modelling test series demonstrates that, compared to static volumetric estimation, the heat quantity calculation based on numerical simulation significantly aids and complements the early design phase, and adds a time-horizon, i.e., a dynamic factor.

Key words:
hydrodynamic and heat transport modelling, geothermal potential, basement highs, UNFC-2009 method, doublet, Peclet number, FEFLOW® modelling software, pore space utilization

References:

Kun, É., Zilahi-Sebess, L., Szanyi, J. 2022: Battonya–Pusztaföldvári-hát térségének nagy entalpiájú geotermikus energia vagyona (I. rész): hidrodinamikai és hőtranszport modell (The high enthalpy geothermal energy resource of the Battonya-Pusztaföldvár High (Part I): hydrodynamic and heat transport model). Földtani Közlöny, 152/1: 53-76. https://doi.org/10.23928/foldt.kozl.2022.152.1.53

Szanyi, J., Kovács, B., Scharek, P. 2009: Geothermal Energy in Hungary: potentials and barriers. European Geologist, 27: 15–18.

Using groundwater model results to derive the distribution of extreme groundwater levels

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The knowledge about the distribution of extreme high or low groundwater levels is needed e.g. to avoid structural damage or to evaluate the operational reliability of wells used for drinking water supply or for heating and cooling of buildings. Typically, distributions of extreme groundwater levels are generated by interpolation between results derived from local extreme value analysis at groundwater observation wells. This may be sufficient in the case of a groundwater head field with few disturbances but may be misleading if either anthropogenic use or hydrogeological conditions lead to sharp changes in groundwater levels. As an alternative, the results of groundwater modelling can be applied to generate the distribution of extreme groundwater levels on a physical basis. In this approach, the simulated groundwater level time series at each computational node are used to derive extreme groundwater levels with a given return period. We used the Gumbel distribution for frequency analysis with annual maximum values; however, the procedure is not restricted to a specific distribution or the selection of observed extreme groundwater levels.
We also developed a correction scheme to account for the deviation between the extreme values estimated based on observed and on simulated groundwater levels, which is due to the imperfect representation of the observed groundwater levels by the groundwater model. We applied the methodology to several Austrian groundwater bodies, for which groundwater models with a simulation period of 25 years are available (Kupfersberger et al., 2020). Moreover, the methodology allows to evaluate the impact of changing boundary conditions (e.g. less groundwater recharge due to shifting meteorological situations) on the estimation of extreme groundwater levels.

Key words:
extreme groundwater levels, Gumbel distribution, groundwater modelling

References:

Kupfersberger, H., Rock, G., Draxler, J. C. 2020: combining groundwater flow modeling and local estimates of extreme groundwater levels to predict the groundwater surface with a return period of 100 years. Geosciences, 10/9: article no. 373. https://doi.org/10.3390/geosciences10090373

Coupling of a saturated zone model with external vadose zone models to simulate land use impacts on groundwater quality at the regional scale

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Intensive agriculture is a prevalent source of anthropogenic contaminants, such as nitrate, pesticides and other agrochemicals, in groundwater globally. Moreover, urbanization effects subsurface temperature, which is warming up even faster than air temperature. An evaluation of these effects on groundwater and naming solutions for their reduction have been supported by groundwater flow and solute/heat transport models on the regional scale. They have been shown to be good practice in number of our case studies.

Our main working tool for modelling of the saturated zone is FEFLOW, which we coupled to various vadose zone models: (i) SIMWASER/STOTRASIM calculates a movement of seepage water and the nitrogen fate in respect to crop rotation patterns, (ii) PEARL describes the fate and subsurface pathways of the widely used herbicides-Metolachlor and its main metabolites, and (iii) SoilTemp simulates dynamic characteristics of heat gradients from below ground heat sources. The coupling is implemented by the exchange of boundary conditions between the models and can be operated either in a sequential mode (i.e. no feedback between the vadose and the saturated zone) or in a direct coupling manner (i.e. time step based interaction).

The Westliches Leibnitzer Feld aquifer in Austria (Klammler et al., 2013; Rock and Kupfersberger, 2018) is the example in which all the mentioned coupled modeling approaches were applied. Such an approach gives an opportunity to relate groundwater quality data to most prominent land uses in a spatial distributed and temporal explicit manner.

Key words:
groundwater model, solute transport model, heat transport model, coupling of models, Leibnizer Feld aquifer, FEFLOW, land use

References:

Klammler, G., Kupfersberger, H., Rock, G. & Fank, J., 2013: Modeling coupled unsaturated and saturated nitrate distribution of the aquifer Westliches Leibnitzer Feld, Austria. Environmental Earth Sciences, 69: 663-678. https://doi.org/10.1007/s12665-013-2302-6

Rock, G., Kupfersberger, H. 2018. 3D modeling of groundwater heat transport in the shallow Westliches Leibnitzer Feld aquifer, Austria. Journal of hydrology, 557: 668-678. https://doi.org/10.1016/j.jhydrol.2017.12.060

Geothermal Conceptual and Numerical Modelling of a Gas-Condensate Field in the Eastern Llanos Basin, Colombia

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This project presents three-dimensional conceptual and numerical flow models of a gas-condensate field in the foothills region of the Eastern Llanos Basin in Colombia. The Eastern Llanos Basin has been the subject of diverse studies for hydrocarbon exploitation. Over the past decade, this region has been assessed for its geothermal potential in currently exploited oil and gas fields. A gas-condensate field located in the foothills of the basin represents a promising opportunity to produce geothermal energy. The conceptual and numerical models integrate geological, geophysical, geochemical and well data to enhance the understanding of the geothermal system in a sedimentary environment. The Leapfrog Geothermal model shows that the gas-condensate field presents a structurally complex architecture, where hydrocarbons and water accumulate in a relatively permeable reservoir. Well data exhibit a constant geothermal gradient, indicating conductive heat transfer. Based on geochemical data and hydrological analyses, it is identified that meteoric recharge occurs in the Andean orogenic belt and fluid flows from NW to SE. TOUGH2 numerical simulations are developed to generate a natural state model and geothermal production scenarios, which give an estimation of water extraction in the field. The thermal and hydraulic parameters were extracted from published experimental and well data. In order to simplify this first geothermal model, and reduce the number of parameters, it is assumed that the field is completely saturated with water. The natural state model temperature field is concordant with measured well data and simulated mass flow direction confirms expected patterns. Production scenarios demonstrate that it is possible to extract water at more than 90 °C without thermal breakthrough during the 30 years simulation. Thermal power calculations yield two optimistic scenarios with more than 30 MWth of heat production, and a conservative scenario with approximately 6 MWth. The conservative scenario provides a better approach to reality with current water production. Thus, this project presents the basis for further studies on geothermal development in actively exploited hydrocarbon fields.

Key words:
geothermal, conceptual model, numerical model, flow simulations, hydrocarbon field, decarbonization

References:

Alfaro, C., Alvarado, I., Manrique, A. 2015: Heat flow evaluation at Eastern Llanos sedimentary basin, Colombia. World geothermal congress, 34: 1–9.

Céspedes, S., Cano, N. A., Foo, G., Jaramillo, D., Martinez, D., Gutiérrez, M., Pataquiba, J., Rojas, J., Cortés, F. B., & Franco, C. A. 2022: Technical and environmental feasibility study of the co-production of crude oil and electrical energy from geothermal resources : first field trial in Colombia. Processes, 10/3: article no. 568. https://doi.org/10.3390/pr10030568

Monitoring of thermal waters in Croatia – the chemical and quantity aspect: case study NW Croatia

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Due to favourable geological conditions, the greatest geothermal potential in Croatia exists in the Pannonian part of the country, with numerous thermal phenomena. The use of thermal aquifers in Croatia is defined by the legislative framework, under which the state requires that the user manages the geothermal resource sustainably. If thermal aquifers are used for balneological, recreational, medical purposes, or bottled and placed on the market, then the management of the use of these resources is according to the Water Act (OG 66/19, 84/21). However, if they are used for energy purposes (for the production of electricity and/or heating), then the management of the use of these resources is according to the Act on Exploration and Exploitation of Hydrocarbons (OG 52/18, 52/19, 30/21). Both acts and their rulebooks do not require obligatory monthly or annual monitoring of chemical parameters and groundwater levels/or yields. The only demands are to monitor the daily amounts of pumped water and thermal wastewater (released in the nature or sewage system). As a consequence, there is lack of systematic data on chemical parameters and groundwater levels/or yields for utilized locations. However, during the DARLINGe and RER7013 projects in period from 2018 till today, monitoring of chemical and isotope parameters, and groundwater levels/or yields were established in selected springs and boreholes in the NW part of Croatia. The selected thermal locations are: B-1 borehole (Stubičke Toplice), Jez-1 (Jezerčica), Vrelo u Bari spring (Tuheljske Toplice), Pučka and Jakobova kupelj springs (Krapinske Toplice), B-1 borehole (Varaždinske Toplice), Vuč-2 borehole (Toplice Sv. Martin na Muri), Mla-3 and KBNZ-1A boreholes (Zagreb). Sampling frequency varied from one to three months. After recent earthquake events (March 2020, Zagreb and December 2020, Petrinja), several locations of thermal waters experienced changes in both chemical and quantitative status. Currently, there is draft of Water management plan for 2022-2027, published in January 2022, which will regulate to establish monitoring of mineral and thermal waters.

Key words:
chemical parameters, groundwater levels, spring yields, monitoring, thermal aquifers, Croatia

References:

Croatian legislation
OG 66/19, 84/21 Water Act
OG 52/18, 52/19, 30/21 Act on Exploration and Exploitation of Hydrocarbons

Making real time groundwater flux measurements part of the equation: a case study in Damme (Belgium)

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Groundwater dynamics play a crucial role in overextraction but also the spreading of a soil and groundwater contamination. However, there is still a big gap in the understanding of the groundwater flow dynamics. Heterogeneities and dynamics are often underestimated and therefore not taken into account. They are of crucial input for successful management and remediation measures. The bulk of the mass of mass often is transported through only a small layer or section within the aquifer and is in cases of seepage into surface water very dependent to rainfall and occurring tidal effects. This study contains the use of novel real-time iFLUX sensors to map the groundwater flow dynamics over time.

The iFLUX sensor provides real-time data on groundwater flow rate and flow direction. The sensor is absolutely unique on a global scale. It consists of multiple bidirectional flow sensors that are superimposed. The sensor probe can be installed directly in the subsoil, riverbed or monitoring well. The measurement setup is unique as it can perform measurements every second, ideal to map rapid changing flow conditions. The measurement range is between 0,5 and 500 cm per day.

We will present the measurement principles and technical aspects of the sensor, together with a case study.

The case study lies in the field of ecosystem restoration. The City Walls of Damme are a nature reserve of 140 hectares, located near walls of Damme. Specific measures were taken to achieve the rewetting of grasslands and swamp forests. A unique real-time hydrological measurement network supports the measures. The network consists of several iFLUX flow sensors to map infiltration, drainage and horizontal flow, combined with a network of groundwater and surface water level, salinity and meteo data.

The nature reserve recently included a dune ridge infiltration to create an inland freshwater reserve in the coast and raise the freshwater table in order to counter the salinization of the coastal zone. The iFLUX sensing network is being expanded in that zone. Flux sensors in combination with EC sensors will continuously monitor the infiltrated freshwater bubble and its surroundings.

Key words:
groundwater, flow, innovative sensors

References:

Patent: Real-time method for measuring fluid flux and flow. Patent number: BE2019/57/57 Cover region: Belgium.
Website: www.ifluxsensing.com

Absolute temperature reconstruction for the previous interglacial period (MIS5e) revealed by noble gases and ^{81}Kr dating of a deep groundwater flow system

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There are a few palaeoclimate reconstruction studies based on noble gas temperatures and radiocarbon datings of groundwater in the Great Hungarian Plain (Stute and Deák, 1989; Varsányi et al., 2011). These studies have been performed on Pleistocene aquifers covering the last 30 to 50 thousand of years, since confined part of the aquifer containing old water is not well defined, an there are limited wells to get samples. These studies provided information about the temperature change during the transition from Late Pleistocene to Holocene. In the Great Hungarian Plain, the temperature increased about 9 °C from the Last Glacial Maximum to the Holocene. However, there is a good chance to find an aquifer which might cover the last 150 kyrs or longer, hence the temperature circumstances of last interglacial (127 to 116 kyrs) might be revealed by means of recharge temperature reconstruction, dating tools and flow modelling. In the North-western part of the Great Hungarian Plain, there is a recharge area of a long aquifer system. The flow path is supposed to be longer than 80 km. Modelling studies have shown that the water ages are expected to be older than 80 kyrs at the discharge area. ^{81}Kr dating will be used in the older part of the aquifer. We expect to determine what temperature prevailed during the last interglacial (MIS 5e), and how it compares to the Holocene. As a first attempt, the noble gas recharge temperature of a 800 m deep well is 12.1 °C with an excellent measure of goodness (chi^2 = 0.64). This value compares very well to Holocene temperatures. ^{81}Kr dating and other ongoing noble gas as well as δ^{18}O measurements will confirm that this part of the flow line represents groundwater recharged during the previous interglacial period and Termination-II.

Key words:
palaeotemperatures, noble gas recharge temperature, 81Kr dating, Holocene, interglacial, glacial

References:

Stute, M., Deak, J. 1989: Environmental isotope study (14 C, 13 C, 18 O, D, noble gases) on deep groundwater circulation systems in Hungary with reference to paleoclimate. Radiocarbon, 31/3: 902-918.
Varsányi, I., Palcsu, L., Kovács, L.O. 2011: Groundwater flow system as an archive of palaeotemperature : noble gas, radiocarbon, stable isotope and geochemical study in the Pannonian Basin, Hungary. Applied geochemistry, 26: 91-104.
Stute, M., Deak, J. 1989: Environmental isotope study (14 C, 13 C, 18 O, D, noble gases) on deep groundwater circulation systems in Hungary with reference to paleoclimate. Radiocarbon, 31/3: 902-918.
Varsányi, I., Palcsu, L., Kovács, L.O. 2011: Groundwater flow system as an archive of palaeotemperature : noble gas, radiocarbon, stable isotope and geochemical study in the Pannonian Basin, Hungary. Applied geochemistry, 26: 91-104.

Droughtmeasure: Weekly groundwater drought assessment in Slovenia

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Droughtmeasure (Slovenian: Sušomer) is a weekly bulletin published by Slovenian Environment Agency on drought in Slovenia. It combines the assessment of agricultural, surface water and groundwater drought (Internet). The main goal of the Droughtmeasure is to provide up-to-date information on drought in Slovenia to the public and to encourage timely action in water-related sectors affected by drought.

Groundwater drought monitoring is performed by groundwater level and stream discharge measurements on the representative national hydrological network. Drought is determined by comparison of the real-time data values with the threshold values, which represent the empirical probability of the phenomenon occurrence in the thirty-year reference period. Groundwater drought is classified in three classes. 75th and 95th percentiles are used as threshold values for moderate and severe drought, respectively, while extreme groundwater drought is declared at extremely low groundwater quantities and needs an expert decision where possible impacts of groundwater drought are considered.

Pending further spatial drought analysis, the "point-source" groundwater drought information from measuring locations is extended to the regional scale. This is performed by assigning common hydrogeological settings from the representative individual measuring stations. Information on drought is finally weighted according to the storage capacity of the aquifers where intergranular aquifers are more heavily weighted compared to karstic and fissured aquifers (GeoZS, 2005).

Groundwater drought assessment as a segment of Droughtmeasure tool is a subject of constant development. The first stages of improvements in the future are going to be devoted to the integration of hydrograph separation information at gauging stations, as well as to the establishment of weekly drought forecasting system. The planned establishment of national groundwater drought impact cadastre will furthermore improve the understanding of the phenomenon itself, which will give us foundation for adaptation to climate change, as groundwater drought has become increasingly common phenomenon in recent decades (Pavlič, 2021).

Key words:
droughtmeasure, Groundwater drought, Real-time data, Hydrological monitoring, Methodology of groundwater drought assessment, Climate change adaptation

References:

Nacionalna baza hidrogeoloških podatkov za opredelitev VTPodV 2005, 2005: Metodologija za opredelitev vodnih teles podzemne vode Republike Slovenije, Geološki zavod Slovenije, Ljubljana, 61 p.

Internet: https://www.meteo.si/uploads/probase/www/agromet/bulletin/drought/sl/

Pavlič, U. 2021: Kazalci okolja v Sloveniji : [PP13] Hidrološka suša podzemnih vod. Agencija RS za okolje, Ljubljana.
Internet: http://kazalci.arso.gov.si/sl/content/hidroloska-susa-podzemnih-vod

The influence of vadose zone characteristics on the solute transport in karst

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Karst aquifers are complex systems characterized by triple porosity. This strong heterogeneity of hydrogeologic structure leads to non-uniform flow and transport patterns. In particular, the characteristics of the vadose (unsaturated) zone have a significant influence on the processes of infiltration, storage, and transport in karst aquifers. Although several studies of these properties have been conducted in recent decades, the processes affecting transport in karst systems remain poorly understood. This gap is addressed in this study by comparing the results of several tracer tests conducted at different locations in western Slovenia. Different types of tracer injection were applied under different hydrological conditions, and sampling was performed either in caves or in karst springs.

Comparison of the results confirmed that flow and transport dynamics are highly dependent on the preceding hydrological conditions, which lead to different saturation levels of the soil and karst rock in the vadose zone. During dry periods, most of the infiltrated precipitation and substances carried with the water are stored in the less permeable parts. Only after further abundant and intense precipitation, the stored substances are gradually washed out. In wet periods, continuous flow through all types of hydraulically connected fissures is enabled and immediate and relatively fast homogeneous transport of solutes with considerable dilution occurs. An important influence of the thickness of the vadose zone on these processes was confirmed. The overlying layers (soil and sediments) may cause an even longer delay in solute transport. All these findings are an important basis for planning more efficient water quality monitoring and protection measures in karst aquifers.

Key words: *soil water, precipitation, stable isotopes of water, infiltration, hillslope vineyard*

Water Contingency Management in the Sava River Basin

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In recent years, groundwater in Slovenia has been threatened by several accidental pollutions: explosion in Melanin factory in Kočevje (2022), train accident in Hrastovlje (2019), fire in Kemis in Vrhnika (2017). To better respond to these types of accidents, emergency planning and water contingency management are crucial. Coordinated emergency response to accidental pollution and flooding on transboundary watercourses in the Sava River basin is the key challenge of the WACOM project (Danube Transnational Program). WACOM aims to reduce the risks of transboundary environmental impacts related to accidental pollution and flooding based on improved cooperation between the project's key stakeholders and to develop a common operating system for activating response protocols in the event of accidental pollution or flooding.

The WACOM project developed several scenarios for the emergency situation in the Sava Basin in Slovenia, Croatia, Bosnia and Herzegovina, and Serbia. In Slovenia, the scenario focused on the derailment of a freight train loaded with several wagons of diesel oil that had spilled into the Sava River at Zidani Most. River Oil Spill Modeling (Kvočka et al., 2021), which simulates the oil spill and predicts the expected propagation time of the spilled oil, can be used to activate response protocols in a timely manner and take appropriate measures to contain further spread of the oil in the Sava River.

In the event of an accidental oil spill, some drinking water sources are also at risk. The most vulnerable water protection zone would be the Sevnica (Kompolje) area, which is fed by the Sava River. This could threaten the drinking water supply in the Sevnica area. Downstream, there are also the Brege and Drnovo well fields, which are part of the Krško aquifer and supply water to Krško and Brežice. In the event of accidental pollution, the pumping of drinking water must be stopped and the use of the water by all residents of the area must be prohibited. Without adequate emergency measures, the pollution could also spread downstream to Croatia and endanger the drinking water sources for Zagreb.

Key words:
groundwater, Sava basin, accidental pollution, water contingency management, oil spill.

References:

Kvočka, D., Žagar, D., Banovec, P. 2021: A review of river oil spill modeling. Water, 13/12: article no. 1620. https://doi.org/10.3390/w13121620

Evaluation of deep geothermal resources in the St. Lawrance Lowlands using shallow thermal response tests

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Geothermal energy is an alternative to be developed as part of a future carbon-free energy mix in Quebec (Canada). The geothermal resources of the St. Lawrence Lowlands sedimentary basin were previously studied to determine its potential for electricity generation from enhanced geothermal systems but direct use of heat from deep aquifers was never assessed. Thus, the objective of this work was to provide a reliable assessment of the geothermal potential of previously identified thermal anomalies that can also be exploited for heating purposes. This was done by assessing heat flow and geothermal resources base as well as inherent uncertainties focusing on a moderate depth of maximum 3 km. Scarce oil wells data were used to estimate the geothermal gradient, surface heat flow, and geothermal resources, taking into account the variability of rocks' thermal properties at the site scale. The results revealed that two sites in particular have a greater heat flow than the expected averages in the basin. These are the Arthabaska and Brossard sites whose average values reach 74.2 mW/m^2 and 108.8 mW/m^2, respectively. Located on Montreal's south shore where energy needs are significant, the Brossard site is of great interest for geothermal development. Further study was conducted in this urban zone to complement scarce oil well data with thermal response tests providing shallow temperature profiles (150 m deep) and confirming the existence of a major thermal anomaly in Brossard. Moving toward the exploitation of geothermal energy, a new well is scheduled to be drilled near Brossard to confirm the elevated heat flow and geothermal gradient. For the purpose of heating buildings and other industrial applications, a temperature of around 30 to 50 °C is expected in potentially permeable formations at 600 to 950 m depth.

Key words: *Energy, Deep Aquifer, Geothermics, Heat Flow, Québec, Canada.*

European Geothermal Fluid Atlas elaborated within the project REFLECT – the Slovenian contribution

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The project REFLECT - Redefining geothermal fluid properties at extreme conditions – aims to prevent problems related to fluid chemistry in geothermal rather than treat them. The Slovenian Geological Society participates in REFLECT as a linked third party where we provide information about geothermal fluids in Slovenia, participate at public events, disseminate new knowledge in the Slovenian society and implement new findings into our research community.
Extreme p, T, c conditions are linked to large uncertainties in current model predictions, therefore, new high-quality high-temperature fluid data was gathered in several Slovenian neighbouring countries but not here as we do not have currently active wells with temperatures above 75 °C. Together with archive data also from Slovenia, new and old data were implemented in a new European geothermal fluid atlas and in predictive models allowing to provide recommendations on how to best operate geothermal systems for sustainable use. For Slovenia, we have provided 12 well data (deepest 3.1 km), 27 fluid sample data (highest temperature 148 °C), 14 rock sample data (deepest from 4 km) and 6 reservoir data (all from E Slovenia). For further information on the fluid atlas, you can look at the recording of the Webinar held online in March 2022: https://bit.ly/3NFG6rg.
Beside these local information, we will try to transfer new findings on: i) The degassing of CO_2 and N_2 saturated water at elevated pressures (up to 100 bar) and temperatures (up to 100 °C) to determine gas dissolution constants; ii) Identification of microorganisms and organic matter in geothermal fluids; iii) PorousMedia4Foam, a software package to investigate hydro-geochemical interactions, with a focus on geothermal, and iv) a Proof-of-Principle-Prototype for a downhole sampling from hot and super-hot wells.

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Key words:
geothermal fluid, geochemistry, higher enthalpy fluids, thermal water

Links:
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Vulnerability assessment of stratified transboundary aquifers using a multi-parameter geochemical approach – A case study of the Mura-Zala Basin

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Regional groundwater flow in the Mura-Zala Basin (MZB), extending between Slovenia, Croatia and Hungary, was characterized in 2013, pointing out vertical stratification in three flow systems: a recent one in alluvial Quaternary aquifers, a shallower one in Pliocene sands, and a deeper but still active one in Upper Pannonian sandstones. As isotope and noble gas studies in shallow aquifers are still rare, our objective was to use these tools to evaluate vulnerability of groundwater resources in the stratified Quaternary to Middle Miocene aquifers.

The first part of our research aims to identify seasonal effects and climatological changes. We have been monitoring physico-chemical and isotopic composition of the water cycle components in the Slovenian and Croatian part of the MZB on a monthly basis since early 2021 in 16 locations, whereas archive data are used for Hungary. Non-weighted monthly precipitation in Ptuj shows oxygen-18 values as -9.01 ±2.50 ‰ whereas groundwater in Plio-Quaternary aquifer has lighter and more homogeneous values with average -10.99 ± 0.12 ‰. The Mura river water has had oxygen-18 values of -10.34 ± 0.49 ‰.

In the second part of our research, we aim to distinguish origin and retention time, search for a possible gap in Pleistocene infiltration, delineate water-rock interaction processes, and determine paleo-infiltration temperatures. A snapshot sampling campaign was performed in October 2021 to determine chemical composition as well as the content of stable isotopes of oxygen, hydrogen and carbon, tritium, radiocarbon, and noble gases in groundwaters in Slovenia and Croatia. We sampled 13 fresh and thermal water wells in East Slovenia and 6 in North Croatia, the wider area of MZB. The outcomes will provide new information on the characteristics of the regional and transboundary flow systems but at the moment only preliminary results of Slovenian samples are available. They show max. tritium activity of 4.90 ± 0.15 TU, carbon-14 from 0.64 to 89.48 pMCa and R/Ra between 0.14-1.43, indicating prevailing atmospheric helium with some crustal component.

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Key words:
transboundary thermal groundwater body, Neogene aquifers, thermal water, isotopes, noble gases, GNIP, GNIR

References:

Szocs, T. et al. 2013: The application of isotope and chemical analyses in managing transboundary groundwater resources, Applied Geochemistry, 32: 95–107. https://doi.org/10.1016/j.apgeochem.2012.10.006

Integrated stratigraphic investigation of a lignite bearing succession to support regional hydrogeological modelling

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Integrating coal- and hydrogeological data is essential for investigating the interference of coal mining and groundwater management when separating the hydrodynamic impact of mine dewatering and groundwater production, or modelling the risks of potential underground coal gasification. This requires high resolution, regionally extended stratigraphy combining the aspects of coal geology with basin scale correlations.

An Upper Miocene lignite bearing succession located at the margin of the Jászság Basin is exploited by open pit mines down to 80–120 metres below surface. Lignite seams have in fact been detected throughout the Jászság Basin in hydrogeological wells down to 1500–1600 metres. To develop regional hydrogeological models, it was essential to understand the stratigraphic relationships between the lignite seams exploited at the basin margin and those detected between the reservoirs of the basin centre.

Facies correlations were made by log-correlation, while basin-scale correlations were performed based on seismic interpretation, in order to ensure a sufficiently high resolution and regionally extended stratigraphy. The geochronology was based on magnetostratigraphy and time series analysis of density logs.

Three distinct lignite formation periods were identified between 9 and 6.3 Ma. The currently exploited lignite succession is the uppermost and youngest (6.8 – 6.3 Ma) unit that is also the main target of the hydrogeological wells in the Jászság Basin. At the same time, the targeted geothermal reservoirs obviously represent the oldest (9.0 – 8.5 Ma) and deepest lignite bearing unit definitely not affected by the lignite mines at the basin margin.

Thus, the differentiation of the effects of in-mine dewatering and other (drinking, industrial) water supply requires accurate hydrogeological models considering both the mine sites and water production of settlements. At the same time the interpretation of apparent hydrodynamic depressions occurring in geothermal reservoirs requires additional investigations considering possible effects other than the coal mining.

Key words: *groundwater, hydrogeological model, regional flow, stratigraphy, lignite*

Hydrogeological conceptualization of Rižana spring karst system

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Quantitative characterization of the hydrodynamic functioning of karst systems requires the definition of realistic hydraulic and geometric parameters (Király, 1998, 2002; Kovács and Perrochet, 2008). Groundwater flow is influenced by the physical conditions of the aquifer and the geology, which directly affect the conductivity and porosity distribution in the system. Therefore, developing a hydrogeological conceptual model of a specific karst aquifer system and its groundwater flow to understand the relationship between the source discharge and the structural/geological environment of a Rižana karst system is very important to define the geometrical and hydrogeological characteristics. One of the basic characteristics of karst systems is a bimodal behaviour, characterised by the presence of a concentrated conduit-dominated flow in an interconnected conduit network system and a groundwater component controlled by the network of fractures and fissures, which usually confirms the large storage capacity of the aquifer.

In this study, we present the Rižana spring and the transboundary aquifer system, the most important water resource for drinking water supply in the Slovenian coastal region (Janža, 2010). A relatively large part of the recharge area, but also the strong surface runoff from the flysch terrain, influence the hydrograms of spring and karst water levels (Prestor, 2002). We present the development of a conceptual model that is key to predicting the available water resources at the beginning of the dry season for water supply, including the vulnerability of the resource to climate change conditions, including droughts and floods.

Key words:
Rižana, karst, groundwater, hydrographs, water supply

References:

Janža, M. 2010: Hydrological modeling in the karst area, Rižana spring catchment, Slovenia. Environmental Earth Sciences, 61: 909-920.

Király, L. 1998: Modeling karst aquifers by the combined discrete channel and continuum approach. Bulletin d'Hydrogéologie de l'Université de Neuchâtel, 16: 77-98.

Király, L. 2002: Karstification and groundwater flow. In: Proceedings of the conference on evolution of karst: from prekarst to cessation. Postojna-Ljubljana. 155-190.

Kovács, A., Perrochet, P. 2008: A quantitative approach to spring hydrograph decomposition. Journal of Hydrology, 352: 16-29.

Prestor, J. 1992: Contribution to the study of relationship between precipitation and outflow from karst aquifer : MSc. University of Ljubljana, FNT, Department of Geology, Ljubljana: 41 str.

Karst springs of the SE Europe as important sources and geoheritage sites

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Karst springs provide potable water to many locations in the world, thus ensuring health, sanitary conditions, food production and economic development. The World Karst Aquifer Mapping project (WOKAM) found that karst covers more than 15 % of the continental ice-free land (Goldscheider et al., 2020) while karst aquifers supply approximately 9.2 % of the world's population with potable water (Stevanović, 2019). Karst water extensive use in irrigation ensures food production especially in arid and poor parts of the world. Therefore, many karst springs largely contribute to SDG 6 – Clean Water and Sanitation and several others (SDGs 1,2,3,5,7,8,15,17).

Large karst springs are especially widely distributed in the SE Europe including Alpine orogenic belt and its branches (Dinarides, Apennines, Carpathians). Some are even discharging entire underground rivers, whose peak flow may exceed 100 m^3/s. The ancient city of Rome obtained 13 m^3/s of water from 11 long aqueducts, some from distances over 90 km. Along the Adriatic coast several major cities were constructed around major karst springs: Trieste, Rijeka, Split, Dubrovnik, Kotor. The first 130 km long mountain pipeline to supply the city of Vienna from the Kaiserbrunn spring was completed in 1873. The intake and aqueducts are engineering masterpiece of that time.

At the final WOKAM map the number of karst springs in Dinaric karst is denser than in any other part of the world. As such, in Bosnia and Herzegovina, there are 8 springs that regularly discharge more than 2000 l/s, while in Montenegro there are 5 such springs.

Under umbrella of the IAH Karst Commission author of this contribution launches an initiative to select, label and protect the world's most important karst springs following several criteria. By support to be provided by local experts it is sure that many karst springs from this region will also be found at that list.

Key words:
Karst springs, water supply, geoheritage, Dinarides, SE Europe

References:

Goldscheider, N., Zhao, C., Auler, A., Bakalowicz, M., Broda, S., Drew, D., Hartmann, J., Jiang, G., Moosdorf, N., Stevanović, Z., Veni, G. 2020: Global distribution of carbonate rocks and karst water resources. Hydrogeology Journal, 28/5: 1661-1677. https://doi.org/10.1007/s10040-020-02139-5

Stevanović, Z. 2019: Karst waters in potable water supply : a global scale overview. Environmental Earth Science. 78: article no. 662; https://doi.org/10.1007/s12665-019-8670-9

Groundwater sampling for monitoring in less productive aquifers

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Due to the increasing awareness of the importance of controlling uncertainty in sampling, many observation points need to be reconsidered. Groundwater status monitoring is mostly carried out in productive aquifers that are locally or regionally important for drinking water supply. However, at sites where significant or potential impacts on groundwater status are expected, monitoring is also required in less permeable strata with a higher proportion of fine fraction. A typical example is the Ljubljana landfill on the northern edge of Ljubljansko barje, where the geological structure is heterogeneous and anisotropic.

The main hydrogeological target zone for monitoring the impact of the landfill is the first gravel layer, which is relatively shallow below the surface. Nevertheless, elevated concentrations of indicative parameters are also present in the layers above the first gravel layer, which can be considered as aquitard. The average values of hydraulic conductivity and seepage velocity are in the order of 10^{-5} m/s and 10^{-3} m/day, respectively, or lower. Standard rules and recommendations for sampling and interpretation of analytical results in such strata are relatively scarce.

Reducing conditions prevail within the geological strata, reflecting the effects of landfill leachate, imissions from other sources in the urban area and the naturally existing reducing environment. Elevated concentrations of Mn, Fe, NO^{2-}, NH^{4+} and S^{2-} are regularly detected. Concentrations tend to be highly variable and scattered due to either inconsistent sampling methodology or analytics. Under these circumstances, it is very difficult to identify and predict individual concentration trends. Based on practical field and laboratory work, we have developed recommendations for monitoring groundwater quality at observation wells to determine the correct procedures for specific groundwater sampling in low-productivity strata.

Key words:
groundwater sampling, monitoring, less productive aquifers

References:

ISO 5667-22:2010 Water quality – Sampling – Part 22: Guidance on the design and installation of groundwater monitoring points.

Groundwater T/He dating as a tool in contaminant source detection – preliminary results

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Žitný Ostrov is an important groundwater reserve in Slovakia, but chemical production in Bratislava throughout the 60´s - 90´s left behind several highly contaminated areas. We have investigated 44 samples in the depths 4 to 70 m, for water stable isotopes, T/He dating, chemistry and 168 potentially hazardous substances. Chemical composition and potentially hazardous substances were monitored in groundwater at a chemical waste deposit in Bratislava (Deposit CHZJD). Water isotope composition $\delta^{18}O$ = -11.05 to -9.98 ‰ (VSMOW) reflects infiltration from the Danube. Local recharge was identified at the site Jelka with $\delta^{18}O$ values of -8.96 to -8.4 ‰. T/He ages in the near-bank area indicate recent infiltration - 0 to 6 years ago in 10 - 70 m depth. Inland sites returned T/He ages between 14.5 and 80.1 years. Prometryne, lindane and atrazine were recorded in depths 11 - 70 m, with concentrations of 0.12 to 1.89 µg/l. Seven of 13 studied sites are pesticide-free, or with concentrations within legal limits. In Žitný Ostrov, prometryne was recorded in shallow and deep samples of young water (0-6 years). The likely source is the liquid waste conduit used for waste-water disposal (Maťová et al., 2021). Therefore, prometryne should be monitored in the Danube and the infiltration area. Lindane and atrazine were recorded in depths 43-53 m corresponding to an GW age of 25 years. Therefore, the contamination recorded in groundwater is not recent. Sources of lindane may be various, it was used in past in agriculture, and its use is officially banned since 2009. Another source could be the Deposit CHZJD located about 10 km N-W, however, concentrations of lindane were very low and recorded only twice. Alternatively, we may explain this as a leaching "event" from the Deposit CHZJD after the construction of the Gabčíkovo Dam in 1992 when the groundwater level has risen 2 m reaching the waste deposit body. To verify this hypothesis, we suggest sampling further to the S-E of the Žitný Ostrov.

Key words:
He/T dating, groundwater age, quaternary aquifer, prometryne, atrazine, lindane

References:

Maťová, V., Ganse, G., Turisová, I., Kviatková, T., Helma, J., Ševčíková, Ľ., Sentpetery, M., Štyriaková, D. 2021: Environmentálne zátaže na Slovensku. Slovenská agentúra životného prostredia, Banská Bystrica: 88 p.

Papp, L., Palcsu, L., Major, Z., Rinyu, L., Tóth, I. 2012: A mass spectrometric line for tritium analysis of water and noble gas measurements from different water amounts in the range of microlitres and millilitres. Isotopes in environmental and health studies, 48/4: 494–511. https://doi.org/10.1080/10256016.2012.679935

Satellite-derived time series of Dinaric Karst aquifer water storage

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Dinaric Karst is the carbonate part of the Dinarides and is the largest karstic body in the region. It has developed in limestone and dolomite of mostly Mesozoic age formed during the passive continental margin sedimentation in the Tethys Ocean. Karstification of these rocks created an extensive water body, the Dinaric Karst Aquifer, which covers the western and north-western part of the Balkan Peninsula and provides an important water source for many countries of the region.

It has already been recognized that the active management of Dinaric Karst and the entire Mediterranean karst water bodies in general could be improved because it is currently poorly established, in some cases with limited or even no water quantity monitoring databases. The continuous measurements and reanalyses provided by remote sensing, such as GRACE (Gravity Recovery and Climate Experiment) and its follow-on mission (GRACE-FO), could bridge this gap, however mostly in regional scales and only for the last couple decades.

Based on the monthly total water storage (TWS) anomaly from a 6-year average derived from GRACE, GRACE-FO and ERA5-Land reanalysis products of water balance components, groundwater variability characteristics of the entire Dinaric Karst Aquifer was analysed. During the analysis, key statistical measures were described on a grid-to-grid basis up to a 0.5° spatial resolution and for the entire karstic aquifer region with data aggregation. The derived time series shows seasonal and long-term water storage fluctuation in the range of approximately 30 cm to 45 cm, the latter using the high spatial resolution products. Research indicates that the surface runoff component explains only a minor amount of the total variation of the water storage, so the TWS provided by GRACE mostly represents the changing amount of subsurface water in the area.

Key words:
Karst, aquifer, GRACE satellite, water balance, storage

References:

Bakalowicz, M. 2015: Karst and karst groundwater resources in the Mediterranean. Environmental Earth Sciences, 74: 5-14. https://doi.org/10.1007/s12665-015-4239-4

Scanlon, B. R., Zhang, Z. Z., Save, H., Wiese, D. N., Landerer, F. W., Long, D., Longuevergne, L. Chen, J. 2016: Global evaluation of new GRACE mascon products for hydrologic applications. Water resources research, 52: 9412-9429. https://doi.org/10.1002/2016WR019494

The impact of temporal variability of groundwater levels on groundwater vulnerability maps in karst terrains – a case example of the Perućac spring catchment area

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Groundwater vulnerability maps represent an essential tool for protecting karst groundwater resources. Vulnerability assessment is usually based on spatial evaluation of various parameters that affect the vulnerability degree and regulate the protection role of the unsaturated zone. Most of these parameters, like soil and geology conditions, are constant and do not change during the year or over several years. In contrast, some parameters, such as the groundwater level, depend on the variability of recharge conditions. By considering the variability of groundwater parameters, vulnerability maps are significantly changed, regardless of the applied vulnerability assessment method. In such circumstances, the obtained groundwater vulnerability maps can reflect the vulnerability degree in different water stages. According to the state of accumulation of karst groundwater, these maps can be used to define protective measures and adequate action in case of a contamination accident.

The catchment of the Perućac spring in western Serbia was selected to assess groundwater vulnerability in two characteristic water storage in the karst aquifer during the hydrological year. The catchment area is characterized by mainly Triassic limestone with well-developed karst porosity. The karst aquifer is primarily recharged with precipitation on the autogenous part of the basin and several periodically active ponors with punctual infiltration. The outflow predominantly occurs through the Perućac karst spring with a flow rate variability of 0.4 to 10 m^3/s.

In these examples, two karst vulnerability assessment methods were applied to estimate groundwater vulnerability in different water stages: PI and COP. Parameters that were found to change in time were the thickness of the unsaturated zone (PI and COP), precipitation (COP), recharge (PI), and infiltration conditions (PI and COP). The latter parameter has the most significant impact on groundwater vulnerability since the presence of concentrated recharge significantly changes the natural protection degree.

Assessment of groundwater vulnerability maps based on different storage conditions in the analysed karst aquifer can be a powerful tool for improved protection and sustainable development of karst basins and analysis of different climate change scenarios and long-term protection.

Key words:
karst groundwater vulnerability maps, parameter changes, Perućac spring, Serbia

References:

Goldscheider, N., Klute, M., Sturm, S., Hötzl, H. 2000: The PI method – a GIS-based approach to mapping groundwater vulnerability with special consideration of karst aquifers. Zeitschrift für angewandte Geologie, 46/3: 157-166.

Vias, J.M., Andreo, B., Perles, M.J., Carrasco, F., Vadillo, I. Jimenez, P. 2006: Proposed method for groundwater vulnerability mapping in carbonate (karstic) aquifers: the COP method. Hydrogeology Journal, 14: 912–925. https://doi.org/10.1007/s10040-006-0023-6

Characterization of Žvepovnik spring – spring with an unpleasant smell in Savinja Valley

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A multi-parameter approach was used to characterize the Žvepovnik sulphur spring in Savinja Valley (Natural Value ID 80218), locally known as Žviponik, one of five known natural sulphur springs documented in Slovenia. The name originates from the term "žveplo", which means sulphur in the Slovenian language. The research was focused to determine the origin of the water, carbon and sulphur, and water retention times. An integrated approach comprised detailed basic geological mapping, geochemical (physico-chemical, elementary), isotopic (δ^2H, δ^{18}O, $\delta^{13}C_{DIC}$, δ^{34}S and ^{3}H), and microbiological analyses. Special interest was to define the origin of the sulphur in the karst spring groundwater, as sulphur springs in karst are rare and insufficiently investigated.

The results represent an important upgrade in understanding of the complexity of groundwater flow and mixing within carbonate environments. The Žvepovnik spring indicates a permanent, deep sulphur-rich source that is diluted by precipitation responsive, near-surface dolomitic groundwater. The spring occurs near the contact between the Triassic dolomite (carbonate aquifer) and the overlying Oligocene shales and volcanoclastic beds (barrier) and is bound to a normal fault of unknown displacement, but one with a hydrogeological role (either as a barrier or a zone of increased permeability). The mixing of sulphur-containing water with the near-surface groundwater is indicated by lower specific electroconductivity and higher oxygen saturation after a rain event.

Geochemically, the Žvepovnik spring indicates that dolomite (and calcite) weathering could be the main source of the major solutes within the aquifer. Based on the geochemical modelling, we can conclude that the spring groundwater is a mixture of sulphate-dissolving waters (the water is in equilibrium with gypsum and/or anhydrite) with carbonate equilibrated waters (undersaturated waters with both minerals, far from equilibrium). The results of δ^2H and δ^{18}O confirm local modern precipitation as the main source of the spring. $\delta^{13}C_{DIC}$ originates from the degradation of organic matter and the dissolution of carbonates. The isotopic values of sulphate ($\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$) indicate four possible sources of the sulphur compounds in the Žvepovnik spring: (1) the most probable is the dissolution of gypsum/anhydrite; (2) barite may be an additional minor source of sulphur; (3) the microbial dissimilatory sulphate reduction; and (4) the oxidation of pyrite as the least probable option.

Key words:
sulphur spring, karst groundwater, geology, hydrogeochemistry, isotopes

References:
Žvab Rožič, P., Polenšek, T., Verbovšek, T., Kanduč, T., Mulec, J., Vreča, P., Strahovnik, L., Rožič, B. 2022: An integrated approach to characterising sulphur karst springs: a case study of the Žvepovnik spring in NE Slovenia. Water, 14/8: article no 1249. https://doi.org/10.3390/w14081249

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