

3.14 Description of the Great Hungarian Plain case study, Hungary

Title of Case Study	Great Hungarian Plain
Location (region, Country)	Great Hungarian Plain, Hungary
Other information	The data and results of this study form part of a general national hydrogeochemical project of the Mining and Geological Survey of Hungary, where hydrogeological-hydrogeochemical characterization of aquifers is supported by multiple isotope and noble gas surveys.

Description of Case Study (background information on the region)

The Great Hungarian Plain (GHP) located East of the Danube River, in the Eastern – South-Eastern part of Hungary is the largest sub-basin of the Pannonian Basin, covering about 52,000 km², and has been extensively studied. This sub-basin developed in the Early-Middle Miocene as a result of a back-arc style extension (Horváth and Royden, 1981; Fodor et al., 2002) and is up to about 7000 meters thick, averaging 2-3000 m. The basin is built up of Upper Miocene sediment successions which form large, regional aquifers. The Nagyalföld and Zagyva Formations (referred as Aquifer 3 in the GHP pilot template) form the upper part of the aquifer, while below them the Újfalu Formation (referred as Aquifer 4) represents the bottom of the lower regional flow system. While the upper part is mainly used in the drinking water supply, the lower part is the main thermal water aquifer. Quaternary sediments, above the Miocene sediment sequence, with various thicknesses form the main drinking water aquifer (Aquifer 2) which is characterised by a large regional flow system. The uppermost, near surface Quaternary sediments host local flow systems (Aquifer 1).

Large scale hydrogeological studies have been carried out since the first part of the 20th century, eg. Erdélyi (1975), however, Stute and Deák (1989) performed the first integrated evaluation applying environmental isotopes, noble gases and hydraulics to regional flow systems. Detailed studies for example by Varsányi et al. (2009, 2011) and Szocs et al. (2015, 2017) have been carried out on the different parts of the GHP.

Description of problem (why is this location chosen for a Cases Study)

The GHP is an important groundwater reservoir. Its aquifers are used from the near surface for domestic or agricultural use to drinking water and industrial supply in the deeper horizons, while the thermal properties of its deep regional aquifer are used amongst other things in balneology, in green houses or for district heating. Several aquifers are transboundary, with recharge areas outside of Hungary. In some regions oil and gas reservoirs can be found at the same depths as the thermal aquifer. These groundwater abstractions, done for different purposes can affect each other's long term abstraction, both related to groundwater pressure and chemistry. As reinjection is not compulsory, pressure drop is already a problem in some areas, and reinjecting in shallower aquifer horizons can cause chemical pollution. While drinking water protection areas and protection zones are defined, as well as geothermal protection zones below 2500 meters, in other cases protection zones are not required by law. As there is an ongoing economic development in Central Europe, with a pronounced agricultural sector development in Hungary and renewable energy share increase, it is important to be able to provide sound information, supported by scientific data to decision makers and potential investors. Hydrogeochemical and isotope data provide independent parameters for numerical modelling and can help to better evaluate the mean residence time

in the different aquifers and their potential vulnerability to pollution. As the GHP is expected to be negatively affected by climate change, an increase in the use of groundwater instead of surface can also be expected.

Methods used in the Case Study (analytical and isotope techniques, modelling)

The GHP case study includes the application of groundwater age indicators $\delta^{18}\text{O}$ - δD , ^{14}C - $\delta^{13}\text{C}$ and limited $^{87}\text{Sr}/^{86}\text{Sr}$, chlorine stable isotope and helium isotope data in addition to the previously applied chemical data. $\delta^{18}\text{O}$ and δD were determined using a GasBench-II preparation system and a Thermo Finnigan delta plus XP spectrometer (Institute for Geochemical Research of the Hungarian Academy of Sciences). ^{14}C measurements were carried out from the DIC content of groundwater precipitated with barium-chloride during sampling after adding saturated NaOH to ensure a pH above 11. The CO_2 gas from the BaCO_3 was converted to lithium carbide, then to acetylene which was then cyclotrimerised to benzene. The radiocarbon activity of benzene was counted by ultra-low level liquid scintillation analyser (PerkinElmer Quantulus 1220; Hydrosys Laboratory Ltd). Stable carbon isotope ratios were determined by conventional stable isotope ratio mass spectrometry using a Thermo Finnigan delta plus XP. Water samples for noble gas analyses were collected in copper tubes and measured by a VG5400 noble gas mass spectrometer. Carbon-13 and noble gases were analysed in the Hertelendi Laboratory of Environmental Studies in the Institute of Nuclear Research of the Hungarian Academy of Sciences. Strontium and chlorine stable isotopes were measured by the University of Waterloo.

Results from this Case Study

Results show groundwater is of meteoric origin even in the deep regional flow systems, with isotopic signatures indicative of the hydrocarbon producing units in the deeper part of the GHP. Based on the carbon isotopes, the groundwater residence times vary from a few thousand to tens of thousands of years. The aquifer is recharged, and abstractions are feasible based on careful studies and where needed, in combination with reinjection. Based on the $^3\text{He}/^4\text{He}$ ratios, not only crustal, but also mantle helium origin were detected not just in the deeper aquifer, but even in the Quaternary sediments. Strontium isotope ratios show enrichment where higher bicarbonate values indicate carbonate dissolution in the Upper Miocene aquifers. Depletion of the heavier ^{37}Cl isotope could be observed along the flow paths.

Impact - how this Case Study contributes to the overall project aims

This case study contributes to the establishment of a harmonized database on groundwater age indicators with data on paleo waters. It helps to define residence time categories for large basins and regional groundwater flow systems. It can contribute to the objectives of the GeoERA RESOURCE project for the characterization of important aquifer types and to produce a map of the fresh groundwater resources of Europe. It shows that isotope hydrogeology can be a useful tool to help subsurface management and quality assessment.

Name of pilot area / aquifers / type: Great Hungarian Plain / Quaternary and upper Miocene sedimentary aquifers / porous		Country: Hungary Region: Great Hungarian Plain	
Study level	Transboundary : ☐ Regional: X Local: ☐ Single well(s): ☐		
Type of observations <i>(choose one of the options, create separate template if needed for each type if each type need specific information)</i>	☐ Short screened observation wells (not pumped) ☐ Long screened observation wells (not pumped) X Pumped wells, long screens in one aquifer ☐ Pumped wells, long screens over multiple aquifers ☐ Springs ☐ Other (eg. research wells; indicate type and information on pumping):		
Approximate location of pilot:			
Geological cross section / conceptual model of the pilot area:			

Name of Shape- / Geopackage file defining the area: HOVER_WP6_HU_GHP_polygon_ETRS.shp		Projection to be used: ETRS 1989 LEAE		
Hydrological parameters:	Mean annual precipitation (mm or range in mm)	Mean annual groundwater recharge (mm or range in mm)	Mean annual groundwater recharge temperature (°C)	Thickness of unsaturated zone (range in m)
	500-550	15-30 mm/year	10.5	1 – 3.8
Pumped wells only		Typical pump discharge of sampled individual well (m³/day): NA	Typical pump discharge of complete well field (m³/day): – <i>If relevant</i>	
List of aquifers and aquitards in pilot area		No. of confined or semiconfined aquifers in pilot area: 3	No. of unconfined aquifers in pilot area: 1	
Aquifer no. (aqf): 4 Aquitard no. (aqt): 0 Aquiclude no. (aqc): 1	Aquifer/aquitard type and/or name	Lithology (Resource WP6 terminology)	Depth range (m)	GW age range (yr)
Aqf-1:	Quaternary fluvial-limnic alternating sedimentary sequence, locally aeolean	alternation of unconsolidated sedimentary hydrogeofacies/ Loess	1 – 55 (thickness 34–51)	No data
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-2:	Quaternary fluvial-limnic alternating sedimentary sequence	alternation of unconsolidated sedimentary hydrogeofacies	cold: 35 – 550 (thickness 85–515) thermal: 550 – 695 (thickness 0–142)	5,000 – >10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-3:	Pliocene - upper Miocene fluvial-limnic alternating sedimentary sequence	alternation of unconsolidated sedimentary hydrogeofacies	125 – 695 (thickness 0–350)	>10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-4:	upper Miocene deltafront and deltaplain sediments	Sandstone	385 – 2370 (thickness 0–1960)	>10,000
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐



Aqc-1:	upper Miocene basin fill	Siltstone, marlstone			
Porosity type	Porous: X	Fissured: ☐	Fissured and porous / dual porosity: ☐	No hydraulically active porosity: ☐	
Applied tracer age indicators (^3H , $^3\text{H}/^3\text{He}$, ^{85}Kr , ^{39}Ar , ^{14}C , ^{36}Cl , ^{81}Kr , ^4He , CFCs, SF_6 , etc.)	Aquifer-2 ^3H , $^3\text{H}/^3\text{He}$, ^{14}C - ^{13}C , ^4He , ^{18}O , D, noble gases				
Applied recharge temperature indicators (^{18}O , D, noble gases)	Aquifer-3 ^3H , $^3\text{H}/^3\text{He}$, ^{14}C - ^{13}C , ^4He , ^{18}O , D, noble gases				
	Aquifer-4 ^3H , $^3\text{H}/^3\text{He}$, ^{14}C - ^{13}C , ^4He , ^{18}O , D, noble gases				
Number of sites (wells/springs) with age indicators	Aquifer-2 1-5: ☐ 5-10: ☐ 10-25: X >25: ☐				
	Aquifer-3 1-5: ☐ 5-10: X 10-25: ☐ >25: ☐				
	Aquifer-4 1-5: ☐ 5-10: ☐ 10-25: X >25: ☐				
GW age range (GAR) GAR-1: Modern (< 60 yr) GAR-2: Old (> 60 yr and 10 kyr) GAR-3: Paleowaters (> 10 kyr)	Aquifer-2 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X				
	Aquifer-3 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X				
	Aquifer-4 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-2: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X				
	Tracer based estimates X				
	Flow and age model simulations ☐				
	Combination of model and tracer estimates ☐				
	Expert judgement: ☐				
	Objective of age dating studies:				
	Basic research or General groundwater management	Assessment of pollutant history		Assessment of the efficiency of remediation and mitigation measures	
				Indication of vulnerability of aquifers and water supply wells	
	X				
	Water Usage (not relevant for observation wells)	Water supply		Irrigation	Industry
X			X		
Geoenergy related activities (not relevant for observation wells)	Shallow Geo-T	Deep Geo-T	Hydrocarbons		
		X			
			Nuclear waste disp.	CO ₂ storage	



Mining activities <i>(not relevant for observation wells)</i>	Construction materials	Minerals / metals	Coal	Other
REFERENCES				
OPEN Access reports and papers (PDF versions made available in EGD repository making them downloadable via maps and keyword / free text searches): Szocs, T., Frape, S., Gwynne, R. Integrating hydrogeochemical and isotope data in studying regional groundwater flow systems in the Great Hungarian Plain. <i>Procedia Earth and Planetary Science</i> 2015; 13, 177–180. DOI: 10.1016/j.proeps.2015.07.041 Szocs, T., Frape, S., Gwynne, R., Palcsu, L. Chlorine stable isotope and helium isotope studies contributing to the understanding of the hydrogeochemical characteristics of old groundwater. <i>Procedia Earth and Planetary Science</i> 2017; 17, 877-880 DOI information: 10.1016/j.proeps.2017.01.004		Reports and papers with restricted access:		
Remarks / other relevant information:				