



Understanding the behaviour of naturally occurring radioactive isotopes in groundwater towards sustainable drinking water resource management

Anita Erőss¹, Reyana Dawn Urbiztondo Garcia¹, Katalin Hegedűs-Csondor¹, Petra Baják¹, Viktor Jobbágy², Bálint Izsák³, Ákos Horváth⁴, Viktória Kohuth-Ötvös⁵, and Márta Vargha³

¹ELTE Eötvös Loránd University, Faculty of Science, Institute of Geography and Earth Sciences, Department of Geology, József and Erzsébet Tóth Endowed Hydrogeology Chair, Budapest, Hungary (eross.anita@ttk.elte.hu)

²Social Organization for Radioecological Cleanliness, Veszprém, Hungary

³Public Health Directorate, National Center for Public Health and Pharmacy, Budapest, Hungary

⁴ELTE Eötvös Loránd University, Faculty of Science, Institute of Physics and Astronomy, Department of Atomic Physics, Budapest, Hungary

⁵Sopron Waterworks Ltd., Sopron, Hungary

Demand for groundwater resources as drinking water is highly increasing worldwide. Groundwater accounts to 92% of drinking water sources also in Hungary. Through rock-water interactions, different elements can be enriched in groundwater including naturally occurring radioactive elements, which may have considerable health risk. Due to the hierarchically organized movement of groundwater, the spatial distribution of dissolved solid content, and associated physical, chemical and kinetic processes are also systematized. Areas of different hydraulic regimes even within the same aquifer are characterized by different geochemical environments, which is decisive in case of the mobility of redox-sensitive elements, such as uranium and radium. The groundwater flow system approach, therefore, helps to understand the origin of the different physicochemical characteristics and components of groundwater. Moreover, the vulnerability to any changes depends also on both the type of the hydraulic regime and the order of the hierarchically nested flow system.

This study aimed to identify the cause of gross alpha activity exceeding the parametric value of 0.1 Bq/L in groundwater-derived drinking water in northwestern part of Hungary using a regional groundwater flow system approach. Sampling of springs, drinking water and thermal wells was performed in 2021 and in 2024. In-situ water quality parameters were recorded on the field. The concentrations of major ions and trace elements, oxygen and hydrogen isotopic ratios and activity concentration of radioactive isotopes (uranium, radium, radon) were determined by laboratory measurements. Local groundwater flow conditions were characterized by pressure-elevation profiles. In drinking water samples total U activity concentration up to 540 mBq/L was measured that can be connected to local geogenic sources related to the metamorphic outcrop of Sopron Mountains and to the Pannonian sediments in its surroundings. The radionuclide-specific

measurements explained that the elevated gross alpha activity identified in several drinking water wells is a result of dissolved uranium favored by the prevailing oxidizing environment of local flow systems and/or recharge areas. Low activity concentrations of ^{226}Ra and ^{222}Rn were measured in all samples except one sample, where 301 mBq/L of ^{226}Ra and 219 Bq/L of ^{222}Rn activity concentration was found. The presence of radium could be attributed to regional flow systems; however, the high concentration of radon activity cannot be accounted for solely by the decay of radium calling for further detailed investigation. The results highlight also that climate change induced groundwater level decline will enhance the problem with uranium. This work has been implemented by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014) project within the framework of Hungary's National Recovery and Resilience Plan supported by the Recovery and Resilience Facility of the European Union. Furthermore, some radioactivity measurements were supported by the open-access scheme of the European Commission's Joint Research Centre (JRC) (Research Infrastructure Access Agreement No. 36227-1).