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Investigation of the contribution of groundwater to the water budget of a shallow soda lake in Hungary by using stable and radioactive isotopes as natural tracers

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Lake Velence is a shallow soda lake in Hungary that is located in a tectonic subsidence in the southern foreland of the Velence Hills. Since the lake is semi-astatic (the volume and level of water in the lake fluctuates frequently), climate has a serious effect on its water budget. Until recently, the groundwater inflow into the lake has been neglected and only the recharge from surface water and rainwater have been taken into account. Because increasing climate change threatens the existence of the lake and its unique ecosystem, it is important to properly assess the components of the lake's water budget.

To understand the role of groundwater for the lake-water quantity and quality, the groundwater flow patterns were mapped constructing pressure-elevation profiles and tomographic potential maps. During our research, 15 water samples were collected from groundwater wells, springs and from the Lake Velence. Physico-chemical properties of the water (e.g. temperature, pH, redox potential, specific electrical conductivity) were recorded during sampling on the field. The samples were analyzed for major ions (Ca, Mg, Na, K, HCO₃, SO₄, Cl). To verify the results of the groundwater flow mapping, stable isotopes (O, H) and radioactive isotopes (Ra, Rn, U) were applied as natural tracers. δD and $\delta^{18}O$ were measured by using PICARRO L2130-i $\delta D/\delta^{18}O$ Ultra High-Precision Isotopic Water Analyzer. ^{222}Rn activity concentration was determined by using TRICARB 1000 TR liquid scintillation detector. The $^{234}U+^{238}U$ and ^{226}Ra activities were measured by a unique method, alpha spectrometry using Nucfilm discs.

The $p(z)$ profiles indicated that recharge areas are dominant south from the lake, while groundwater discharges along the lake's shoreline. According to the tomographic potential maps, the regional groundwater flow travels from the Velence Hills toward the regional base level (River Danube). The water chemistry analysis indicated that the majority of the water samples can be classified as Ca-Na-HCO₃ and Ca-Na-HCO₃-Cl-SO₄ type waters. δD measures were between -98.4 and -13.4‰; while $\delta^{18}O$ values were between -13.4 and 0.15‰. Most of the samples are characterized by relatively high $^{234}U+^{238}U$ activity concentration (up to 497 mBq L⁻¹). Based on δD

and $\delta^{18}\text{O}$ values, groups of groundwater having different recharge environment, can be distinguished. This is in line with the results of the groundwater mapping: a deep regional flow system with longer residence time and more shallow local flow systems with shorter residence time can be identified. The dominance of recharge areas and the presence of local flow systems can be further supported by the $^{234}\text{U}+^{238}\text{U}$ measurements, because uranium can be mobilized by the groundwater primarily under oxidizing conditions. It was revealed that groundwater contribute to the lake's water budget and the lake is fed by local groundwater flow systems known to be more sensible for the climate changes.

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