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Geological factors controlling radon hazardous concentration in groundwater

T. A. Przylibski

Wroclaw University of Technology, Faculty of Geoengineering, Mining and Geology, Institute of Mining, Division of Geology and Mineral Waters, Wybrzeze S. Wyspianskiego 27, 50-370 Wroclaw, Poland (tadeusz.przylibski@pwr.wroc.pl)

Radon waters are classified as waters containing more than 100 Bq/L of Rn-222. In many regions radon groundwaters are commonly used as a tap waters. Exploitation of radon groundwater without removing radon out of water in the intake may be hazardous for the consumers. Radon removing is relatively simple and cheap, and may be achieved trough the degassing of tapped water. The following factors are crucial for the genesis of radon (Rn-222) and changes in its concentration in groundwaters: the content of parent Ra-226 in the reservoir rock, the emanation coefficient of the reservoir rock, mixing of various groundwater components. Simplifying the geochemical characterisctics of Ra-226, one can say that the highest radium contents outside uranium deposits could be expected above all in crystalline rocks such as granites, ryolites and gneisses, and among sedimentary rocks – in fine-grained rocks – mudstones and clay rocks. Therefore the highest content of Rn-222 is characteristic of groundwaters flowing through the abovementioned rocks. What is very important for the genesis of groundwater dissolved Rn-222 is not only the total content of Ra-226 in the aquifer, but also the distribution of this isotope's atoms in relation to the surface of mineral grains (crystals) and crack surfaces. Only if Ra-226 atoms lie in the outer zone of grains (crystals), they can be the source of Rn-222 atoms released directly or indirectly into pores and fissures. If the pores and fissures are filled with free groundwater, then the radon dissolved in this water can migrate with it. Therefore particularly high Rn-222 concentration values can be expected in groundwaters circulating in zones of strongly cracked reservoir rocks, i.e. in the weathering zone, reaching the depth of several dozen meters below ground surface, as well as in zones of brittle tectonic deformations. The number of Rn-222 atoms formed in groundwater as a result of the decay of Ra-226 ion (Ra2+) dissolved in this water occasionally reaches 1 percent, and usually does not exceed 0.1 percent of the total number of dissolved Rn-222 atoms it contains. The transport of Rn-222 atoms is mostly due to water movement. As a rule, radon atoms cannot travel farther than several to several dozen meters away from their birthplace. Sporadically this distance can reach 100 – 200 metres. This fact is related to Rn-222 half-life (T), which lasts 3.8224 days, so after a bit more than 38 days (10·T), less than 0.098 percent of the initial number of Rn-222 atoms dissolved in groundwater will remain. Within this time, groundwater can travel no farther than dozens, or sporadically hundreds of meters. Rn-222 atoms can travel the farthest with fissure groundwaters, whose movement may be the fastest. The distances are even longer in karst aquifers, but waters there are usually characterized by low radon concentrations. The mixing of various groundwater components results in substantial differences in Rn-222 concentration in water discharged from a spring or an intake (a well or a borehole). The mixing process often determines radon concentration changes in time too. As a rule, radon is dissolved in the contemporary infiltration component of shallow circulation. Therefore, the usually more mineralised older waters of deeper circulation are poorer in radon. Radon presence in mineral waters (TDS > 1g/L) is very often related to their dilution by radon waters of shallow circulation and contemporary infiltration. It is also noteworthy that the described radon behaviour in groundwater environment is linked to widely observed large fluctuations in Rn-222 concentration in the water of one spring (intake) in time, often reaching 25 – 50 percent of the mean value. In the case of mixed waters with a large proportion of shallow infiltration component, whose volume reveals substantial seasonal variations (e.g. after abundant rain or snowfall or intensive thawing), these fluctuations can reach 100 or even 200 percent of the mean Rn-222 concentration value. The local character of radon supply into a spring or intake (the last dozens of meters before water appears in the intake or spring) results in the fact that concentration changes of groundwater dissolved Rn-222 vary by several orders of magnitude over the distance of several dozen, or even a dozen meters. It means that intakes situated a dozen or several dozen meters apart may contain waters with radon contents of the order of 1 Bq/L or several thousand Bq/L.