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EVALUATION OF THE DEPENDENCE OF THE ACTIVITY CONCENTRATIONS RATIOS 234U/238U AND 235U/238U IN WATERS ON THE 238U ACTIVITY CONCENTRATION

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In routine radiochemical analyzes of water, especially drinking water, in recent years we have analyzed more than 4,000 water samples for uranium 238U, 235U and 234U isotope contents by ICP/SFMS method in the ALS Scandinavia AB laboratory, Luleå, Sweden and the Central Analytical Laboratory of ÚJV Řež, a.s., Husinec – Řež, in the Czech Republic. By statistical processing of an extensive set of data, we evaluated the interesting patterns that are discussed in this article and which can significantly help in the evaluation and interpretation of measurements of natural radionuclides in drinking water.

While the 235U/238U activity ratios in natural waters and rocks are more or less constant, the 234U/238U activity ratios in natural waters, especially groundwater, but also in some soils, sediments and rocks, usually do not correspond to the calculated theoretical values. The 234U/238U activity ratio is 1.0 only in closed systems, e.g. in some minerals that have not been subjected to any chemical effect for a long time. In waters, the activity ratio of 234U/238U is often many times higher than 1.0. The reason for this is the fact that 234U in rocks is formed by the decay of its parent nuclide, 238U. After one alpha decay and two beta decays, the daughter 234U is released from its original position in the crystal lattice of the mineral due to "atomic recoil", and upon subsequent chemical attack of the rock by groundwater,234U atoms enter the aquatic environment much more easily than its parent 238U atoms. Thus, uranium-234 isotope is much more chemically reactive than uranium-238 in the solid sample, and as a result, the 234U/238U activity ratio in waters and in the formed secondary minerals and rocks is much higher than 1.0. The fact that 234Th, the short-term alpha decay product of 238U, can be released to a greater extent into the aqueous environment after atomic recoil, where it decays to 234U very quickly, also contributes in part to the increase in 234U activity against 238U.

We confirmed these facts by statistical processing of an extensive data set of 238U, 235U and 234U contents in the analyzed water samples. The 235U/238U activity ratio is constant within the uncertainties of the determination, no exception was found. In contrast, the activity ratio of 234U/238U is significantly higher than 1.0, the overall average of this ratio is 1.9. The value of this ratio depends on the hydro-chemical conditions of the environment, but it can generally be said that the lower the total volume concentration of uranium resp. the volume activity of 238U in groundwater, the higher the value of this ratio. If the volume activity of 238U in groundwater decreases from XX-XXX Bq/L to 0.0XX Bq/L, the 95% percentile distribution of the 234U/238U ratio will increase from about 3 to 8-10.

The work also discusses relatively "rare cases" where the activity ratio 234U/238U is less than 1.0.

The values of these activity ratios were also evaluated for about 500 analyzed solid samples.

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