Application of bomb-36Cl in dating modern groundwater

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Tritium (3H) is one of the useful environmental tracers for age dating of modern groundwater (~50 years) because its concentrations in precipitation increased largely as a result of atmospheric nuclear tests conducted during the 1950s and 1960s. Due to the short half-life of 3H (12.43 years), however, the 3H "bomb pulse" has been attenuated recently through radioactive decay. Hence, another dating tool which can evaluate the residence time of modern groundwater is necessary in place of 3H.

The application of long-lived radionuclide chlorine-36 (36Cl) was proposed by Bentley et al. (1982) as a replacement for 3H. The fallout rates of 36Cl also increased primarily as a result of nuclear tests at oceanic sites in the 1950s. The 36Cl has a half-life of 301000 years which is much longer than that of 3H, so the attenuation through radioactive decay can be neglected for the time scale of several decades to centuries. Therefore, the 36Cl bomb pulse has a potential to be a dating tool for modern groundwater. However, there are few detailed studies using the 36Cl bomb pulse as a tracer or dating tool in groundwater.

The objectives of this study are:

- to clarify the relationship between 36Cl content and residence time of groundwater.
- to demonstrate background level and peak level of the 36Cl bomb pulse and investigate the potential use of 36Cl as a dating tool for modern groundwater.

Groundwater samples were collected at the Oderbruch polder, Germany. In the Oderbruch polder, the shallow aquifer is mainly recharged by the infiltration from the Oder River. Sampling points are located along the flow path.

Another groundwater samples were collected at Tsukuba Upland, Ibaraki, Japan. The sampling depth ranges from 7 m to 240 m below the surface.

The chloride concentrations of groundwater samples were determined by ion chromatography. For 36Cl analysis, groundwater samples were prepared as AgCl. The 36Cl/Cl ratios of groundwater samples were measured by the AMS (accelerator mass spectrometry) at the Applied Accelerator Division, Research Facility Center for Science and Technology, University of Tsukuba.

From the measurements, background level of 36Cl/Cl ratios at the Oderbruch polder was estimated to be 7E-14 - 9E-14. The 36Cl/Cl ratios of groundwater samples which were dated by 3H/3He method (Sultenfuss and Massmann, 2004) showed good agreement with Dye-3 ice core data (Synal et al., 1990). Consequently, it was revealed that the distribution of bomb-produced 36Cl (bomb-36Cl) in groundwater corresponded to the fallout pulse.

The depth profile of 36Cl/Cl ratios of groundwater samples at Tsukuba Upland showed a peak around 30 m below the surface, and it agreed well with that of 3H concentrations (Yasuhara, 2004). From the 36Cl/Cl ratios of groundwater deeper than 55 m, background level at Tsukuba Upland was estimated to be 1E-13 - 2E-13. From the time series of 36Cl/Cl ratios at Tsukuba Upland estimated using Dye-3 data, residence time of groundwater was estimated to be about 50 years at 40 m and 35 years at 30 m.

In conclusion, it was demonstrated that the residence time of groundwater in a region could be estimated if the determination or estimation of time series of 36Cl/Cl ratios was possible.

References

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