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Characterization of natural groundwater colloids and quantitative evaluation of cesium and iodine removal by colloids

EUNGYEONG KIM[1], DR. DONG-HUN KIM[2], HO YOUNG JO[3] AND BYUNG-GON CHAE[2]

[1]Korea Institute of Geoscience and Mineral Resources (KIGAM)
[2]Korea Institute of Geoscience and Mineral Resources
[3]Department of Earth and Environmental Sciences, Korea University

Colloid-facilitated radionuclide transport in groundwater depends on the mineralogical and hydrogeochemical properties of naturally occurring colloids, but quantitative evaluations have largely relied on synthetic systems or indirect concentration differences before and after filtration. This study directly characterized colloids in natural groundwater and quantified cesium (Cs) and iodine (I) removal under different hydrogeochemical conditions. Groundwater samples were collected from three locations (MW1-14m, MW1-21m, and MW3-21.5m) within granitic bedrock in the Sokcho-Yangyang area, South Korea. Groundwater containing colloids (Ø <0.2 μm) was analyzed using ICP-OES, ICP-MS, zeta potential measurements, nanoparticle size distribution, and TOC analysis. Filtered colloids were further characterized by μ-XRF and TEM-EDX to determine the chemical composition and mineral phases. Batch adsorption experiments were performed for 48 h after spiking the groundwater samples with CsI at concentrations of $7.5\ 10^{-5}$, $7.5\ 10^{-7}$, and $7.5\ 10^{-8}$ M. In the MW1-14m and MW1-21m samples, characterized by relatively low salinity and neutral to mildly alkaline pH, the colloidal phase removed a measurable fraction of Cs and I from solution. μ-XRF and TEM-EDX analyses identified iron (oxy)hydroxides (i.e., goethite, ferrihydrite, and lepidocrocite) as dominant colloidal components. Cs removal exceeded that of I. The negatively charged surfaces of iron (oxy)hydroxide colloids may have enhanced Cs adsorption under these hydrogeochemical conditions. In contrast, the high-salinity MW3-21.5m sample showed limited Cs and I removal, despite the presence of dispersed colloids in suspension. High concentrations of dissolved ions reduced radionuclide adsorption through competitive interactions. These results indicate that colloid-mediated radionuclide retention in natural groundwater is controlled primarily by salinity, ionic competition, and mineral composition of the colloids. Particle size distribution and electrokinetic properties alone do not control radionuclide removal under natural conditions.

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