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Characterization of Particulate Matters in the Pripyat River in Chernobyl: Inhibition Effect of Natural Organic Matter on Adsorption of Radiocesium

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Radiocesium has been released to environment originated from nuclear weapon tests and nuclear accidents. Among various sources, the nuclear accidents in Chernobyl and Fukushima have caused serious contaminations in land-surface around these areas due to the deposition of the radionuclides dispersed via atmosphere as aerosols including radiocesium and radioiodine. Subsequently, radiocesium can be transported via rivers into oceans. In the soil-river-sediment system, radiocesium has a high affinity for particulate matters, in particular for clay minerals, at least in Fukushima area [1]. In our study, it was suggested that the high affinity has been caused by the specific adsorption to frayed edge site (FES) and interlayer site in 2:1 phyllosilicate by the formation of inner-sphere (IS) complexes [2]. However, it has been indicated that adsorption of cesium (Cs) to clay minerals can be blocked by natural organic matters (NOM) that adsorb on the mineral surface [2]. NOM are ubiquitous and play various important roles on the adsorption of metal ions on particulate matters, which includes inhibition effect on the adsorption of metal ions on the particulate matters by its coating on the surface. Therefore, it is suggested that high availability of Cs in soils in the presence of organic matters can be explained by the blocking of access of Cs to specific adsorption sites on the clay minerals.

In this study, therefore, adsorption experiment of Cs on particulate matters in the Pripyat River have been conducted to study whether the blocking effect is affecting the adsorption behavior of Cs. For this purpose, particulate matters were collected by filtration using filtration by 3 and 0.45 μm pore size membrane filters in August 2013 from the Pripyat River in the Chernobyl City, 17.5 km downstream from the Chernobyl Nuclear Power Plants. Based on Cs L_{III}-edge EXAFS analysis, it was suggested that a large amount of dissolved organic carbon (DOC) in the Pripyat River (= 18 mg/L) is responsible for the larger dissolved fraction of cesium in the river.

To characterize the particulate matter, distribution image of organic matters on the particulate matter was obtained by a compact Scanning Transmission X-ray Microscope (cSTXM) newly developed at BL-13A in Photon Factory [3]. Spatial resolution of the cSTXM is about 50 nm at K-edge of carbon (C). After the cSTXM imaging, characterization of NOM was conducted by near edge X-ray absorption fine structure (NEXAFS) at C K-edge measured for the NOM by cSTXM. The image analysis and extraction of NEXAFS spectra were performed using by aXis2000.

To support the blocking effect of NOM, cSTXM and scanning electron microscopy (SEM; KEYENCE VE-9800) analyses were conducted for the particulate matters [4]. The particulate matters collected from the Pripyat River were dispersed into water by supersonic wave for 5 min. The water droplet including the particulate matter was dropped on a 50-nm-thick Si_3N_4.

The cSTXM analysis provided a chemical map of C and aluminum (Al) obtained by subtraction of the optical density (OD) images taken at post-edge by pre-edge for the absorption edge of C or Al. The image showed that the organic substances attached to the rim of the clay particle indicated by the map of Al. It was also suggested that the blocking effect can be effective by the coating of organic matters on the clay minerals. NEXAFS spectra at C K-edge showed that the organic materials associated with the clay are humic substances, as revealed by the presence of functional groups such as carboxylate, phenolate, and aromatic carbons in the NEXAFS spectra.

References

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