

Research Group for Interfacial Reaction Field Chemistry

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The research objectives of this group are to explore novel chemical reactions of aqueous species of elements at liquid-solid and liquid-liquid interfaces to contribute to environmental chemistry, actinide chemistry, and waste treatment.

More concretely, we focus our research on elucidation on environmental radionuclide migration and radioactive waste treatment. The research on elucidation on environmental radionuclide migration has two research fields, Fukushima and Ningyo-toge. Research on the environmental aspects of the Fukushima issues includes circulation of radiocesium in Fukushima forest and decontamination of contaminated substances. Research on Ningyo-toge includes chemistry of uranium and radium in soil, rock, and groundwater in the context with environmental safety. Research and development on radioactive waste treatment includes development of breakthrough technologies particularly for difficult-to-treat elements.

Research on radiocesium migration in the terrestrial environment

Since the Fukushima Daiichi nuclear power plant accident, our group has been investigating radiocesium (Cs) migration in the terrestrial environment, particularly in the forest environment. The forest environment is a very complex system, where inorganic substances (minerals, ions) are influenced by numerous living substances (microorganisms including mushrooms, insects, plants, and so on) and organic substances originated from those living substances. This complexity makes the elucidation of Cs migration in the forest environment difficult.

In 2020, we reported the chemical states of Cs in trees [1]. We revealed that the Cs in some kinds of trees living in Fukushima is present as hydrated ion which water molecules are bound to Cs ion. Binding of hydrated Cs ion to the tree biomolecules is believed to be weak, which is consistent with the knowledge that Cs easily migrates in trees. This result also agrees with the knowledge on shiitake mushroom culture with a wood-log contaminated with Cs; when shiitake absorbs water and nutrients from the log to grow, Cs in the log is also flowed and absorbed by shiitake [2]. Moreover, a few papers by other research organizations reported that the Cs in wild mushrooms are mostly water-soluble. These papers indicate that the Cs absorbed by plants and mushrooms are bioavailable and stored in their bodies as water-soluble form. Plants and mushrooms in Fukushima forest have been absorbing Cs from soil; however, in soil the fraction of the Cs in bioavailable forms (water soluble and ion exchangeable forms) is small [3]. To construct a whole picture of Cs migration in the forest environment, we are investigating microbial activities towards soil minerals (microbial solubilization of the Cs fixed in minerals) and Cs reflux from dead plants and mushrooms to soil.

Research and development of radioactive waste treatment

The main objective radionuclides of this research are anionic radionuclides with long half-lives. They are ^{79}Se , ^{99}Tc , and ^{129}I . Most of the other fission product radionuclides are cations in acid aqueous solution. Numerous methods have been proposed to recover or inorganically fix (solidify) cationic radionuclides because most natural and synthetic substances have negative charges. It is however very difficult for those anionic radionuclides, particularly Tc and I. These two elements are present as monovalent anions ($\text{Tc}^{\text{VI}}\text{O}_4^-$, I^- , IO_3^-) under a wide range of environmental conditions, and their stable complexes and inorganic solids are hardly known. In 2020, we reported that IO_3^- is effectively recovered from aqueous solutions by being taken up in structures of barite (BaSO_4) (see Highlight) and ettringite (hydrated calcium aluminum sulfate mineral) when those minerals form [4, 5]. Our current efforts are focused on R&D on methods for pre- and post-coprecipitation: catalytic oxidation of I^- to IO_3^- and containment of iodine in solidified bodies.

In terms of other radionuclide extraction from waste liquids, our group has been proposing several new extracting agents in various approaches. There are some unavoidable issues of solvent extraction; the ordinary extraction process requires a large amount of organic solvents because of, e.g., loss of extractant through mutual dissolution of organic and aqueous solutions. To explore a new potential extraction system that overcomes this problem, we designed a fluorosolvent-water biphasic extraction system using perfluorinated alkanes and developed a new fluorosolvent extractant, tris(4,4,5,5,6,6,7,7,7-nonafluoroheptyl) phosphate (TFP) by focusing on excellent chemical properties of fluorosolvents, including low toxicity, low viscosity, inflammability, chemical stability, and incapability of being mixed with both water and organic solutions [6]. TFP exhibited a superior extraction performance for Ln^{III} than a conventional organic extractant, tri-*n*-butyl phosphate (TBP), despite the tendency of hydrocarbon fluorination to reduce the extraction performance. Furthermore, separation factors among Ln^{III} elements (e.g., the ability to separate La^{III} from Eu^{III} and Lu^{III}) by TFP were higher than those by TBP, suggesting that the Ln^{III} separation performance of TFP is superior to that of TBP.

References

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