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Fukushima Review II on Migration of radionuclides from the Fukushima Daiichi Nuclear Power Plant accident

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In March 2011, an earthquake of magnitude 9, followed by a tsunami, triggered a major nuclear accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) in Japan. This accident resulted in substantial release of radionuclides into the atmosphere and the ocean. Seven years after the accident, several studies have documented both the initial dispersal and secondary migration of radiocesium, a primary radionuclide emitted by the accident, throughout the environment surrounding FDNPP (Buesseler *et al*., 2017; Kaeriyama, 2017; Yamaguchi *et al*., 2016; Hirose, 2016; Evrard *et al*., 2015; Steinauser *et al*., 2014; Yoshida and Takahashi, 2012). However, several important questions have yet to be resolved, including those addressing (a) the emission processes of radionuclides from FDNPP, which is strongly related to the initial chemical species of radionuclides and (b) the geochemical processes that influenced secondary migration of the radionulcides, including the desorption rate of radiocesium bound to particulate matter in aquatic systems.

This special issue is entitled, "Fukushima Review II", and is the sequel to "Fukushima Review", which was published as a special issue of Geochemical Journal in 2012 (Ebihara *et al*., 2012). The first issue successfully delivered scientific knowledge on the migration of radionuclides emitted from the FDNPP, up to one year after the accident, as evidenced from high citations of several manuscripts in the volume (i.e., Qin *et al*., 2012; Aoyama *et al*., 2012; Sakaguchi *et al*., 2012). The publication of "Fukushima Review II" was proposed following the well-received scientific session "Radionuclide fate and transport after the Fukushima accident: Identifying what we have learned and remaining knowledge gaps", convened at Goldschmidt 2016 (Yokohama, Japan, June 2016), five years after the accident. We are very pleased that 12 manuscripts with important scientific knowledge were included in this volume, which can be categorized into the two subject areas (a) and (b) described above.

In category (a), the first contribution is an invited review by Kajino *et al*. (2018) regarding atmospheric modeling of radionuclides from the FDNPP, which describes the first step of dispersion of the radionuclides in the environment. Tsuruta *et al*.'s (2018) analysis of radiocesium found in particulate matter collected hourly (using filter tapes) from the atmosphere during the accident significantly contributes to our understanding of the initial dispersion process of the radionuclides. The initial chemical form of radiocesium released into the atmosphere is still an open question. The discovery of micrometer-sized spherical particles that contained high concentrations of radiocesium by Adachi *et al*. (2013) stimulated follow-up studies of water insoluble, Cs-enriched particles in the environment surrounding the FDNPP. In this issue, Yamaguchi *et al*. (2018) and Satou *et al*. (2018) demonstrated that new types of the Cs-enriched particles, with larger size non-spherical shapes, can be found in environment. Miura *et al*. (2018) detected micrometer-spherical particles, as reported in Adachi *et al*. (2013), in suspended matters in river water and discuss their importance as a form of radiocesium in environment.

Geochemical studies on various processes affecting the radionuclides released from the FDNPP, which can be categorized into (b), were reported in this issue for radioiodine in rainwater (Matsumura *et al*., 2018), possible secondary dispersion of radiocesium from biogenic sources (Nakagawa *et al*., 2018), solid-water distribution of radiocesium in river water (Tanaka *et al*., 2018), desorption of radiocesium from suspended particles in river-brackish-seawater system (Sakaguchi *et al*., 2018), and vertical profiles of radiocesium in marine sediment off the coast of Fukushima (Fukuda *et al*., 2018).

Additional studies in this issue contributing to the

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progress of FDNPP research focused on analysis of radionuclides other than cesium and development of new analytical methods for radionulide detection. Takahata *et al*. (2018) detected tritium from the Fukushima Dai-ichi nuclear accident in the Pacific Ocean and related their finding to tritium production in the FDNPP. Yang *et al*. (2018) developed an improved method to measure ^{134}Cs, ^{135}Cs, and ^{137}Cs activities in marine sediments with the goal of using the relative abundance of these isotopes to fingerprint radiocesium from FDNPP.

The FDNPP accident was a serious and regrettable accident in human history in terms of our loss of faith in science and technology. Considering the fact that future accidents of this kind must be avoided at all costs, it is our great task to clarify what happened at the FDNPP and to understand the factors controlling migration of the released radionuclides in the environment. From this perspective, we hope that the manuscripts in this issue contribute to a better understanding of the cause of the accident, initial dispersion and secondary migration of the radionuclides, and precise prediction of their future behaviors in the environment.

Finally, we would like to thank all those who contributed to this special issue. We are grateful to all the reviewers for their constructive and critical comments and suggestions, which improved the quality of the manuscripts. We would also like to thank Prof. Hiroyuki Kagi, the editor-in-chief of Geochemical Journal, for his encouragement and support in publishing this special issue. Without their support, the publication of this issue would not have been possible.

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