Transformation of Iodine Species in Soil under Upland Field and Submerged Paddy Field Conditions

Elevated radioiodine level is observed in atmosphere and soil around nuclear-fuel reprocessing plants. Exposure to radioiodine is hazardous, particularly for children, because radioiodine is accumulated in the thyroid gland. For food safety, considerable attention should be paid to the behavior of radioiodine in the agricultural environment. Once long-half-life ^{129}I (1.6×10^7 y) enters the cycle of biogeochemical systems, it will behave in the same way as stable ^{127}I. Major iodine species in soil include iodide (I^-), iodate (IO_3^-), and organically bound iodine. Only small amounts of iodide can bind to soil components, so that iodide dissolveds in water and thereby absorbed by plants and migrates into groundwater. Iodate is relatively immobile in soil because it can be adsorbed onto soil minerals.

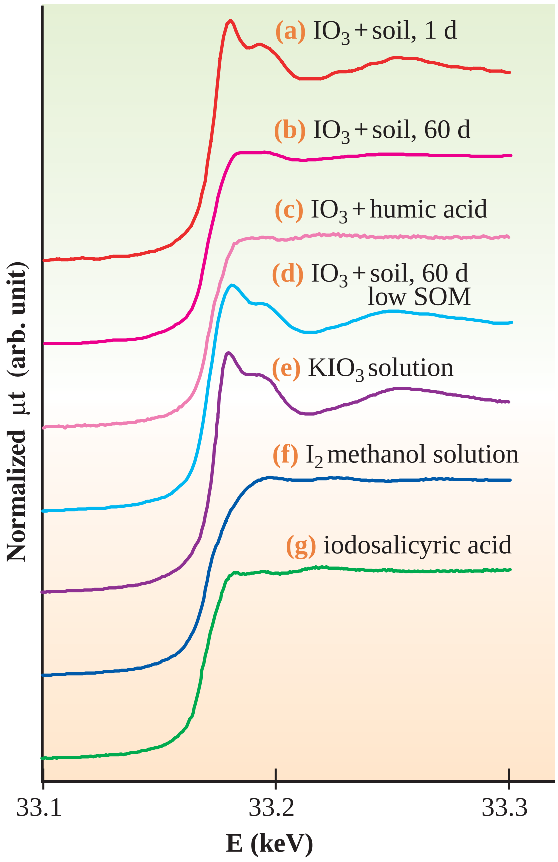

Fig. 1. I *K*-edge XANES spectra after incubation with humic acid and soils of different organic matter contents under upland field conditions **(a-d)** and XANES spectra of reference iodine compounds **(e-g)**.

Besides, organically bound iodine is considered as sink of iodine in soil. The iodine concentration in paddy field soil was substantially lower than that in upland fields and forest soils [1]. This suggests that agricultural practices strongly influence the speciation and mobility of iodine in soil. We investigated whether the transformation of the iodine occurs in agricultural soil systems and thereby affect their fate in the soil environment.

To simulate iodine transformation in upland fields, potassium iodate (KIO_3) dissolved in deionized distilled water was sprayed on mixture of soil and humic acid extracted from volcanic ash soil. The moist soil/iodate mixtures were then incubated at 308 K for 1 d and 60 d. Iodine *K*-edge (33.2 keV) XANES data acquisition was conducted at beamline **BL01B1** in the fluorescence mode. The post-edge feature of IO_3^- remained after 1-d incubation (Figs. 1(a) and 1(e)); however, it disappeared after 60-d incubation (Fig. 1(b)). The XANES post-edge feature of iodine after 60-d incubation appeared similar to that of I_2 or organoiodine (Figs. 1(f) and 1(g)). This indicated that IO_3^- in contact with soil was transformed to I_2 or organoiodine after 60 d under upland field conditions. The post-edge feature of IO_3^- also disappeared when IO_3^- was incubated with humic acid extracted from soil (Fig. 1(c)). The sterilization of soil by γ-ray irradiation did not affect XANES spectra after 60-d incubation, suggesting that microbial activity was not important for iodine transformation under upland field conditions. On the contrary, the post-edge feature of IO_3^- remained after 60-d incubation in soil of low soil organic matter (SOM) content (Fig. 1(d)). Therefore, SOM such as humic acid has a role in reducing IO_3^- to I_2. The highly volatile I_2 cannot remain in soil when it is present as I_2. Since I_2 is highly reactive with organic compounds, the formed I_2 likely associates with SOM as organoiodine in upland fields.

To simulate iodine transformation in paddy fields, KIO_3 dissolved in irrigation water was added to non-sterilized and γ-ray-sterilized soil at a soil-to-solution ratio of 1:1.5. The submerged soil was incubated for 30 d. The post-edge feature of IO_3^- totally disappeared after incubation for 30 d when the soil was not sterilized (Fig. 2(a)). On the other hand, the post-edge feature of spiked IO_3^- remained in sterilized soil after 30 d of incubation (Fig. 2(b)). As a result, the consumption of oxygen attributable to biological activity and the subsequent development of anaerobic conditions could be the causes for the disappearance of IO_3^- in paddy soil. The post-edge feature of iodine in non-sterilized soils after 30 d of incubation appeared similar to that of reference I_2 or organic iodine. Iodide dissolves in solution in contact with soil and iodine associates with paddy soils either as I_2 or organoiodine under anaerobic conditions [2].

In conclusion, reductive reaction of IO_3^- caused the formation of I_2 in agricultural soils. In upland fields, SOM is responsible for the reductive reaction. In submerged paddy fields, the development of reduction conditions attributable to microbial activity is responsible for the reductive reaction. Because I_2 is highly reactive with organic compounds, the formed I_2 may associate with SOM as organoiodine. I_2 or organoiodine is a potential source of iodine absorbed by plants (Fig. 3).

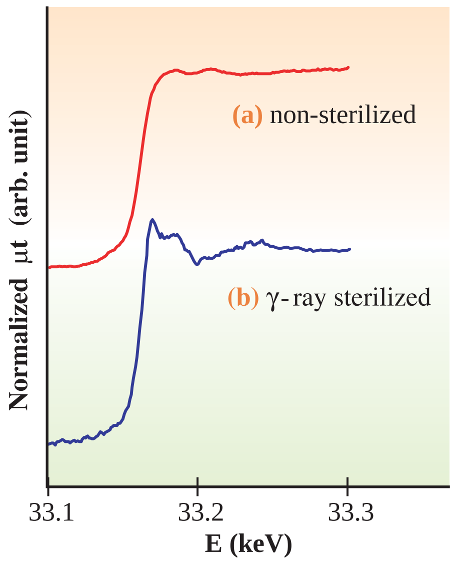

Fig. 2. I *K*-edge XANES spectra after 30-d incubation with soil under submerged paddy field conditions.

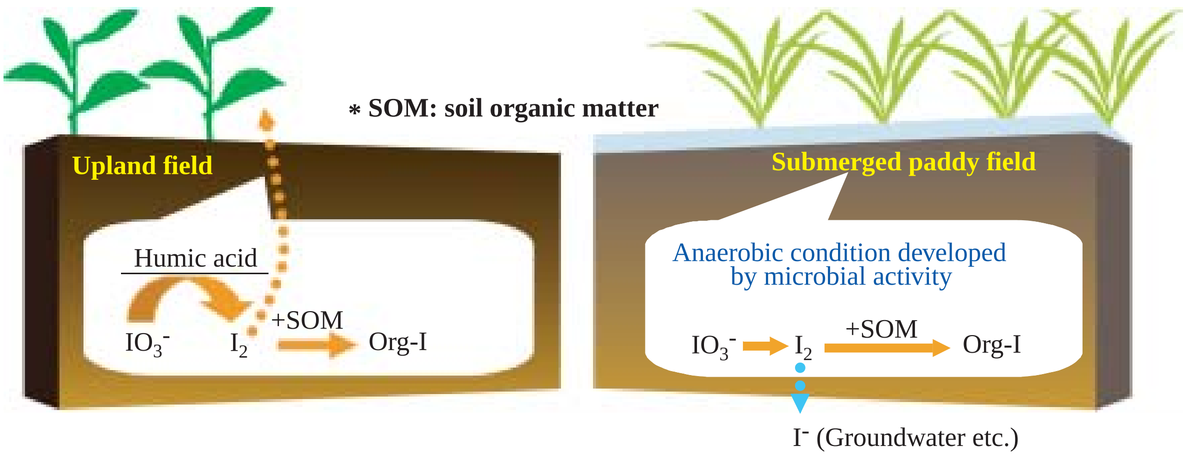

Fig. 3. Iodine transformation in upland and submerged paddy field soils.

N. Yamaguchi[a,*], M. Nakano[b] and H. Tanida[c]

[a] Soil Environment Division National Institute for Agro-environmental Sciences
[b] Research Institute of Soil Science and Technology
[c] SPring-8 / JASRI

*E-mail: nyamag@affrc.go.jp

References

[1] K. Yuita: Soil Sci. Plant Nutr. **38** (1992) 281.
[2] *N. Yamaguchi, M. Nakano, H. Tanida, H. Fujiwara and N. Kihou: J. Environmental Radioactivity* ***86*** *(2006) 212.*