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Fate and transport of radionuclides in soil-water environment. Review.

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The ease in which radionuclides move through the environment and are taken up by plants and animals is governed by their chemical forms and by site-specific environmental characteristics. The objective of this paper is to review basic mechanisms of the behavior of radiocesium and radiostrontium in the environment after the nuclear accident. Our understanding of radionuclide's speciation and migration processes seems to be adequate and explains similarities and differences of radiocesium (r-Cs) behavior in the environment after Fukushima and Chernobyl accidents.

Climate and geographical conditions in Fukushima Prefecture of Japan and Chernobyl's near-field zone are obviously different. In particular, precipitation differs substantially, with the annual average for Fukushima being about 3 times higher than at Chernobyl. The landscapes and soils also differ significantly. What is more, the speciation of r-Cs in the releases was distinct (large fraction of radionuclides was deposited as fuel particles in 30-km zone around Chernobyl NPP, while in Fukushima radiocesium is mostly part of condensation particles including glassy hot particles).

Radiocesium (r-Cs) in the environment is strongly bound to soil and sediment particles containing micaceous clay minerals (illite, vermiculite, etc.), which is associated with two basic processes – high selective reversible sorption and fixation. The r-Cs distribution coefficient K_d in Fukushima rivers was found to be 1-2 orders of magnitude higher than corresponding values for rivers and surface runoff of Chernobyl area. This is indicative of higher ability of Fukushima soils and sediments to bind r-Cs. Dissolved r-Cs wash-off for Fukushima river watersheds is essentially slower than those for Chernobyl. However, steeper slopes and higher precipitation in Fukushima area cause higher erosion and higher particulate r-Cs wash-off. For a comparable time after the accident the total r-Cs wash-off from contaminated catchments in Fukushima is up to one order of magnitude higher than in Chernobyl.

Long-term dynamics of radionuclide concentrations in rivers is approached from the standpoint of basic mechanisms of radionuclide sorption-desorption, fixation, vertical migration in catchment soils. Corresponding semi-empirical models are presented and discussed. For the Chernobyl case, radiostrontium (r-Sr) was shown to be more mobile and moving faster in dissolved state with surface runoff and river water in comparison with r-Cs. Similar pattern was observed for Mayak area in South Ural (Russia), where r-Sr was traced up to 1500 km away from the release point migrating through Techa-Iset'-Tobol-Irtysh-Ob' river system. On the other hand, r-Cs bound to clay particles settles down in Techa river reservoirs and is transported with river water only insignificantly.

For the first 3 years after the accident vertical migration of r-Cs in soils of Fukushima catchments was found to be faster than in Chernobyl due to higher air temperature, higher precipitation and higher biological activity in top soil. However, with time this process slows down because of higher r-Cs retardation in Fukushima soils.

In Fukushima case, extreme floods during typhoons lead to substantial reduction in dose rate on floodplain areas due to sedimentation of relatively clean material and burial of contaminated top soil layer.

In general, due to higher precipitation, higher temperatures and higher biological activities in soils, self-purification of the environment and natural attenuation in Fukushima is essentially faster than in Chernobyl area.