Fukushima and Chernobyl: similarities and differences of radiocesium fate and transport in soil-water environment

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Abstract

The ease with which radionuclide moves through the environment and is taken up by plants and animals is determined by its speciation and site-specific environmental characteristics. The peculiarities in climate, geomorphology and ^{137}Cs speciation in the fallout were demonstrated to lead to differences in migration rates of ^{137}Cs in the environment and rates of its natural attenuation. It has been revealed that in the exclusion zone the Fukushima-derived ^{137}Cs is strongly bound to soil and sediment particles, which reduces potential bioavailability of this radionuclide. Substantial fraction of the deposited ^{137}Cs on soil of the exclusion zone were found to be incorporated in hot glassy particles ("Cs balls") insoluble in water. These particles are decomposing in the environment essentially slower as compared with Chernobyl derived fuel particles. Wash-off from the slopes of contaminated catchments and river transport are key long-term pathways for radionuclide dispersal from contaminated areas after the Fukushima accident. The climate conditions for the Fukushima Prefecture of Japan are characterized by higher annual precipitation (1300-1800 mm/year) with maximum rainstorm events during typhoon season. Typhoons Etou in 2015 and Hagibis in 2019 demonstrated the substantial redistribution of ^{137}Cs on river watersheds and floodplains and in some cases natural self-decontamination occurred. Steep slopes of Fukushima catchments are conducive to higher erosion and higher particulate r-Cs wash-off. Irrigation ponds in Okuma and Futaba towns demonstrated persistent behavior of ^{137}Cs similar to the closed lakes in Chernobyl, its concentration is decreasing slowly and showing regular seasonal variations: the ^{137}Cs concentrations tend to grow in the summer and decrease in the winter.

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Introduction

The ease with which radionuclide moves through the environment and is taken up by plants and animals is determined by its speciation and site-specific environmental characteristics. The peculiarities in climate, geomorphology and ^{137}Cs speciation in the fallout were demonstrated to lead to differences in migration rates of ^{137}Cs in the environment and rates of its natural attenuation.

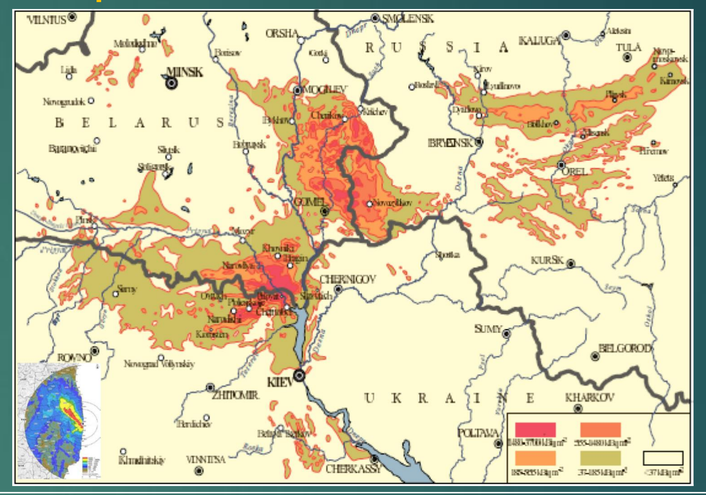
Results

It has been revealed that in the exclusion zone the Fukushima-derived ^{137}Cs is strongly bound to soil and sediment particles, which reduces potential bioavailability of this radionuclide. Substantial fraction of the deposited ^{137}Cs on soil of the exclusion zone were found to be incorporated in hot glassy particles ("Cs balls") insoluble in water. These particles are decomposing in the environment essentially slower as compared with Chernobyl derived fuel particles. Wash-off from the slopes of contaminated catchments and river transport are key long-term pathways for radionuclide dispersal from contaminated areas after the Fukushima accident. The climate conditions for the Fukushima Prefecture of Japan are characterized by higher annual precipitation (1300-1800 mm/year) with maximum rainstorm events during typhoon season. Typhoons Etou in 2015 and Hagibis in 2019 demonstrated the substantial redistribution of ^{137}Cs on river watersheds and floodplains and in some cases natural self-decontamination occurred. Steep slopes of Fukushima catchments are conducive to higher erosion and higher particulate r-Cs wash-off. Irrigation ponds in Okuma and Futaba towns demonstrated persistent behavior of ^{137}Cs similar to the closed lakes in Chernobyl, its concentration is decreasing slowly and showing regular seasonal variations: the ^{137}Cs concentrations tend to grow in the summer and decrease in the winter.

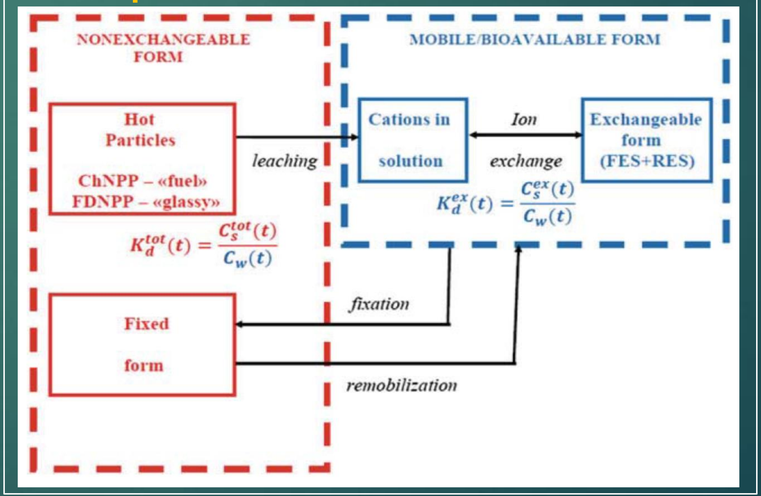
Soil and bottom sediments core sampling at Glubokoe, Azbuchin lakes and at Ogaki dam at FDNPP exclusion zone

Cooling Pond at Chernobyl and

Fukushima compared to Chernobyl: Comparable levels but over smaller area



Conceptual model of transformation of r-Cs speciation in soil-water environment



Main messages

- Fukushima-derived r-Cs is stronger bound by soil and sediment particles as compared with Chernobyl, Mayak and NWT-origin r-Cs. This promotes faster scavenging of r-Cs in surface waters and prevailing transport of r-Cs on suspended material with surface runoff and river flow;
- Higher precipitation in the Fukushima region, steep slopes and higher average air temperatures promote higher wash-off of radiocesium as compared to Chernobyl and faster natural attenuation of contaminated catchments;
- Extreme flood events during typhoons result in fast and efficient redistribution of radioactive contamination in Fukushima.
- Similar to Chernobyl, dam reservoirs in Fukushima play important role of traps and prevent r-Cs transport downstream.

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