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Radiocesium wash-off, river transport and redistribution in fluvial system after the Fukushima Dai-ichi nuclear power plant accident

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Processes responsible for long-term changes in environmental radioactivity after the Fukushima accident are currently high on the agenda. Dynamics of particulate and dissolved radiocesium (r-Cs) has been studied on a number of water bodies, namely Abukuma River, Niida River and Maeda River, the dam reservoirs of Yokokawa (Ota River), Sakashita (Kuma River), Ogaki (Ukedo River) and Shinobu (Abukuma River) and four heavily contaminated irrigation ponds in Okuma town (Inkyozaka, Suzuuchi, Funasawa, Kashiramori). Water samples were collected for dissolved and particulate r-Cs analysis at multiple sites for these water bodies. Wash-off from slopes of contaminated catchments and river transport are key long-term pathways for radionuclide dispersal from contaminated areas after the Fukushima accident. The climate and geographical conditions for the Fukushima Prefecture of Japan are characterized by relatively high annual precipitation (1300-1800 mm/year) and steep slopes which promote higher erosion and higher particulate r-Cs wash-off. At the same time, the r-Cs distribution coefficient K_d in Fukushima rivers was found to be at least an order of magnitude higher than the corresponding values for Chernobyl-derived r-Cs and r-Cs resulting from nuclear weapon tests (NWT) in European rivers. The normalized dissolved wash-off coefficient for Fukushima river watersheds, based on the measured dissolved r-Cs activity concentrations was found to be 1-2 orders of magnitude lower than those for Chernobyl and NWT fallout. In the irrigation ponds r-Cs showed a persistent behavior and was characterized by regular seasonal variations: r-Cs concentrations tend to grow during summer and decrease during winter. Speciation analysis for Okuma ponds showed a much higher exchangeability of r-Cs in bottom sediments than catchment soils. Several methodologies to collect water samples and to separate the particulate and dissolved fractions have been used and showed comparable results for all water bodies under study. For all rivers, reservoirs, and ponds higher values of K_d (r-Cs) have been confirmed when compared with Chernobyl-derived r-Cs

in European water bodies. Some observations demonstrated remobilization of r-Cs at river mouths compared to upstream sections which could be explained by the change of river water hydrochemistry from upstream to the mouth, specifically a substantial increase in the concentration of major r-Cs competing cations for selective sorption sites on the suspended matter. Some dam reservoirs and ponds were subjected to integrated suspended sediment sampling. For the dam reservoirs, the particulate r-Cs activity concentration has been found to be water depth-dependent. Sediment cores collected at eight sites along the Abukuma river floodplain in 2018 and during October-November 2019, right after Typhoon Hagibis occurred in the middle of October 2019, demonstrated substantial redistribution of r-Cs due to erosion and redeposition during heavy rainfall and extreme flood. Bottom sediments coring in the dam reservoirs allowed estimation of the average sedimentation rate in the reservoirs and the rate of r-Cs accumulation. This research was partially supported by the Japan Society for the Promotion of Science (JSPS), Grant-in-aid for Scientific Research (B) (18H03389), bilateral project No. 18-55-50002 of Russian Foundation for Basic Research (RFBR) and JSPS.