10-year monitoring of ^{137}Cs transport in 30 river monitoring sites in 80km from the Fukushima Daiichi nuclear power plant

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Ten years have passed since the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP). As a result of this accident, about 2.7 PBq of ^{137}Cs was deposited on the terrestrial area in eastern Japan. It is essential to clarify the transport of ^{137}Cs through rivers to ensure residents' safety living in the basin and understand the supply of ^{137}Cs to the ocean. Therefore, 30 river monitoring stations were set up in nine river basins located within 80 km of the FDNPP. We measured the radiocesium concentrations in suspended and dissolved forms and conducted a continuous observation of water level and turbidity at those stations. Monitoring began in 2011 at six stations located on the Abukuma River and its tributary. At the other 24 stations, monitoring began in 2012. Suspended sediment (SS) samplers were set up at each station to measure the suspended ^{137}Cs concentrations. SS samples were collected from the sampler every few weeks to months, dried, and the radioactivity concentration was measured with a germanium semiconductor detector. 60-100 L of river water was collected every few months to half a year. The river water was filtered through a membrane filter with a pore size of 0.45 μm, and the radiocesium dissolved in the filtrate was collected by the AMP coprecipitation method or the cation exchange resin method. Then, the radioactivity concentration was measured by a germanium semiconductor detector. The solid-liquid distribution coefficient (Kd) of ^{137}Cs was calculated by dividing the suspended ^{137}Cs concentration by the dissolved ^{137}Cs concentration. Water discharge (Q) and SS concentration (SSC) were calculated from water level and turbidity data. The SS flux (Qss) was calculated by multiplying Q by SSC, and the ^{137}Cs flux (L) was calculated by multiplying Qss by the ^{137}Cs concentration in the relevant period. During the ten years after the FDNPP accident, the concentration of ^{137}Cs in both dissolved and suspended forms decreased significantly. After a sharp decrease in concentration during the first year after the accident, a slightly slower declining trend was observed after the second year. The effective environmental half-lives (T_{eff}) of ^{137}Cs concentrations were about 0.11(4 sites) and 0.57 years (6sites) in the dissolved and suspended forms in the first year after the FDNPP accident. After the second year, the T_{eff}s were about 2.4 years in the dissolved form (29 sites) and about 3.0 years in the suspended form (29 sites). The Kd did not show any temporal change, and its geometric mean value was 2.9×10^5 L/kg (30 sites). The ^{137}Cs flux from the Abukuma River to the Pacific Ocean from August 2011 to December 2019 was about 49 TBq, which is 2.4% of the initial deposition. The ^{137}Cs discharged from August 2011 to March 2012 is 0.9%, while the flux transported in 2019 has decreased to about 0.19%. About 80 % of the 2019 flux was released in October when the heavy rains by Typhoon Hagibis occurred. After the Chernobyl nuclear power plant accident in European rivers, the decline in the ^{137}Cs concentration became more gradual around the seventh year. Similar trends may be observed in Fukushima's rivers. Also, there are still concerns that ^{137}Cs may be supplied to downstream areas via rivers from the forests located upstream. Therefore, it is necessary to continue to accumulated data and monitor the trends.

Keywords: Cesium-137, River, Fukushima Daiichi nuclear power plant accident

