Ten years behavior of radionuclides in the North Pacific Ocean derived from TEPCO Fukushima Dai-ichi Nuclear Power Plant accident

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As a result of the big earthquake and the huge Tsunami on 11 March 2011, and the reactor accident at the Fukushima Daiichi Nuclear Power Plant, hereafter FNPP1, due to total power loss made meltdown of three cores of FNPP1. Then, a large amount of radionuclides was released into the environment. The total amount of radiocaesium released into the environment is one of the global concerns, as the major long-lived radionuclides released from the accident were long-lived radiocaesium, namely 134Cs and 137Cs. Based on the law of conservation of mass, I and my collaborators had estimated the total amount of released radiocaesium based on ocean observations of radiocaesium activity concentration taking into account mass balance. By observing the North Pacific Ocean by the ships and deposition estimated by three atmospheric transport model results, we were able to estimate the total amount of 137Cs in the North Pacific. This amount was estimated to be 15-18 PBq. This estimation has been verified by two methods. From the results of coastal modeling, the total amount of direct discharge of 137Cs was 3.5 ± 0.7 PBq, which was the first and most accurate result. Since the amount of direct release is accurately determined, the amount of 137Cs released into the atmosphere is also properly determined in consideration of mass balance. After injected into the ocean, half of the injected radiocaesium remained in the surface layer while the second half of the injected radiocaesium subducted into the two mode waters, namely STMW and CMW. On the other hand, most of the deposited radiocaesium on land stayed there and a very small amount of radiocaesium was transported to the ocean.
In the wide area of the western North Pacific Ocean, the radiocaesium concentrations increased rapidly due to the atmospheric deposition and the direct discharge, afterward they decreased rapidly, or they were gradually decreasing depending on the distance and direction from the FNPP1 site. In the adjacent seas of the North Pacific Ocean (the Sea of Japan, the East China Sea, and the Bering Sea), features of temporal variations of radiocaesium activity concentrations were different, as delayed increases of radiocaesium activity concentrations were observed due to advection/transport of water masses from highly contaminated areas with different time scales. In general, the transport processes of FNPP1 derived radiocaesium in the surface layer in the North Pacific Ocean will depend mainly on two current systems –the subarctic gyre and the subtropical gyre. The main surface pathway of Fukushima derived radiocaesium followed Kuroshio and Kuroshio extension and arrived at the west coast of the American continent in 2014/2015 and bifurcated to north and south. The northern branch reached at the Bering Sea while the behaviors of the southern branch are unclear due to fewer observations. Regarding the transport of radiocaesium to the East China Sea and the Sea of Japan through the ocean interior, a part of the FNPP1-derived radiocaesium in the STMW moved west and reached the bottom of the north of the East China Sea (ECS), then the signal abducted to the surface layer and continued to the Sea of Japan (SOJ). The apparent half-life due to advection-diffusion after radioactive decay correction was 18.9 years for the Ogasawara region for the period 2012-2020 and 12.3 years for 2016-2020, while it is slightly longer at 22.4 years for 2016-2020 in the southern part of the Sea of Japan. On the other hand, in the vicinity of Yonaguni Island, there is no change or a slight increase in 2017-2020. Also, the 134Cs / 137Cs ratio increased in the vicinity of Yonaguni Island, reaching ca. 0.5 in 2020, which is about the same as those observed at Ogasawara and the Sea of Japan. These transports might mainly follow the subtropical gyre.

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