

Concentration of Cs of seawater and zooplankton in the western North Pacific one month after the Fukushima accident

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In March 2011, an accident at the Fukushima Daiichi nuclear power plant (FNPP-AC) was caused by the Tohoku earthquake and tsunami. As a result, gigantic amount of artificial radionuclides were emitted to the atmosphere, land and ocean. To investigate the transport of radionuclides to the ocean and their dispersion, we conducted a cruise with the R/V Mirai in the western North Pacific about one month after the FNPP-AC and measured caesium (¹³⁴Cs and ¹³⁷Cs) in seawater and zooplankton. In addition, a numerical simulation of radionuclide dispersion in the ocean was conducted with a particle-tracking model using surface currents reproduced by the Japan Coastal Ocean Predictability Experiment 2 (JCOPE2) model. A modified one-way nested global/regional air quality forecasting system (AQF) was also applied to simulate the time/space variations in the ¹³⁷Cs aeolian deposition flux over the western North Pacific. ¹³⁷Cs concentration in surface seawater ranged from 0.004 to 0.284 Bq kg⁻¹ (average 0.048 Bq kg⁻¹). Samples from stations off Fukushima and Miyagi had higher ¹³⁷Cs concentrations than those at other stations. ¹³⁷Cs concentrations north of 40N were relatively higher than those south of 35N. These ranged from a few times to two orders of magnitude higher than those measured before FNPP-AC. ¹³⁴Cs were detected while not detectable before FNPP-AC and ¹³⁴Cs/¹³⁷Cs were estimated to be 1 within measurement error. Because the ¹³⁴Cs/¹³⁷Cs ratio of drain water and air from the FNPP was reported to be nearly 1, radionuclides from the FNPP were likely transported to nearly all of the stations. At station K2, the ¹³⁷Cs concentration in zooplankton from the surface mixed layer was 1.72 Bq kg-ww-1 and that in zooplankton from the subsurface layer was 3.16 Bq kg-ww-1. The corresponding values at S1 were 4.01 Bq kg-ww-1 in the surface mixed layer and 4.31 Bq kg-ww-1 in the subsurface layer. ¹³⁴Cs was also detected in all zooplankton, with ¹³⁴Cs/¹³⁷Cs ratios of nearly 1 within measurement error. The ¹³⁷Cs concentration of zooplankton around Japan was less than 0.1 Bq kg-ww-1 during the last decade. Thus, the observed concentrations were one to two orders higher than before 11 March. Previously reported values of the concentration factor (CF), the ratio of the Cs concentration of zooplankton to that of ambient, range from 10 to 100, whereas we estimated the CF for zooplankton in this study to range from 200 to 840, an order of magnitude higher than previous observations. The above CF has been estimated under steady state. Thus these might not be applied to our case that Cs concentration of seawater and zooplankton were measured one month after FNPP-AC and both concentrations were still transient. Moreover a possible explanation to this enrichment is that particulate materials with high ¹³⁴Cs and ¹³⁷Cs that originated in the FNPP were adsorbed onto the zooplankton, rather than taken up by them, and collected along with the zooplankton. JCOPE2 results showed that plumes of radioactively contaminated water extended north-eastward near the coast to 40N and eastward along the northern flank of the Kuroshio extension about one month after the FNPP-AC. The high ¹³⁷Cs concentration off Fukushima and Miyagi can be qualitatively explained by dispersion of the water discharged directly into the ocean from the FNPP. In contrast, the JCOPE2 result showed no detectable ¹³⁷Cs north-east of the FNPP beyond 40N, 150E, despite relatively large values observed there during the cruise, suggesting that radionuclides were transported to distant locations to the north-east by another mechanism. An AQF model indicated that ¹³⁷Cs emitted from the FNPP would have been deposited over a wide area of the western North Pacific. Therefore, the observed high ¹³⁴Cs and ¹³⁷Cs concentration in seawater, SS and zooplankton might be attributable mainly to this aeolian input of particles with high ¹³⁴Cs and ¹³⁷Cs concentration.

Keywords: Fukushima Daiichi NPP, Caesium, Western North Pacific, seawater, zooplankton, numerical simulation