Long-term simulation of oceanic ^{137}Cs with direct release and river discharge after the Fukushima Dai-ichi Nuclear Power Plant accident

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A series of accidents at the Fukushima Dai-ichi Nuclear Power Plant (1F NPP) following the Great East Japan Earthquake and tsunami of 11 March 2011 resulted in the release of radioactive materials to the ocean. We used the Regional Ocean Model System (ROMS) to simulate the ^{137}Cs activity in the oceanic area off Fukushima, with the sources of radioactivity being direct release, atmospheric deposition, river discharge, and inflow across the domain boundary. Note that atmospheric fallout was only considered for the first month after the accident.

Measured137 Cs activity adjacent to the 1F NPP decreased exponentially with a variation of about one order of magnitude by July 2016 and has not decreased since then. The measured ^{137}Cs activity was higher than the one before the 1F NPP accident, therefore direct release from the 1F NPP site have continued to present. One possible reason for the no decrease in measured ^{137}Cs activity since July 2016 is the impact of river discharge. In this study, measured ^{137}Cs activity adjacent to the 1F NPP was assumed to be due to direct release from the 1F NPP site, and the direct release rate was estimated by the comparison between measured data adjacent to the 1F NPP and model simulation with unit release rate.

The longer-term simulation was carried out by the estimated direct release rate until September 2020. Because the spatiotemporal variability of ^{137}Cs activity was large, the simulated results were compared with the annual averaged observed ^{137}Cs activity distribution. Simulated ^{137}Cs activity was in good agreement with measurement data in 2013. The simulated ^{137}Cs activity become smaller than the observed ones in the coastal area away from the 1F NPP site after 2014. This suggests that the impact of river discharge has become relatively larger with the decrease of direct release. Normalized annual averaged ^{137}Cs activity distributions in the regional ocean were similar for each year from 2013 to 2016. This result suggests that the annual averaged distribution is predictable. The heavy rainfall caused by the typhoon in October 2019 increased the measured ^{137}Cs activity adjacent to the 1F NPP, 2F NPP and Iwasawa coast, and the increase continued for 6 months. The simulated ^{137}Cs activity with direct release were about 7 times smaller than the measured one for 6 months after heavy rain. The increase in river flow rate due to heavy rainfall was on a scale of a few days or less, and the discharge of dissolved forms is considered to be on a much shorter time scale than six months. Since the dissolved ^{137}Cs flux from rivers was small and the impact was expected to be short-lived, it is suggested that the impact may be due to re-leaching from particle ^{137}Cs deposited in estuaries.

Keywords: Fukushima Daiichi Nuclear Power Plant accident, Radioactive cesium, Regional ocean model, Direct release, River discharge

