Regional-scale oceanic simulations of ^{137}Cs, ^{90}Sr, ^{3}H radioactivity directly released by 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 earthquake and tsunami of 11 March 2011 resulted in the release of radioactive materials to the ocean by two major pathways, direct release from the accident site and atmospheric deposition. Additional release pathways by river input and runoff from 1F NPP site with precipitation and were also effective for coastal zone in the specific periods before starting direct release on March 26 2011. The activities attributable to the direct release were observed adjacent to the 1F NPP site. The sea side impermeable wall was closed at 26 October 2015. We estimated the direct release rate of ^{137}Cs, ^{90}Sr and ^{3}H for more than four-and-a-half years after the accident by the Regional Ocean Model System (ROMS).

Direct release rate of ^{137}Cs were estimated by comparing simulated results and measured activities adjacent to the 1F NPP site (adjacent to 5,6 discharge and south discharge). Direct release rate of ^{137}Cs was estimated to be 2.2×10^{14} Bq/day and decreased exponentially with time to be 3.9×10^{9} Bq/day by 26 October 2015. Estimated direct release rate have exponentially decreased with constant rate since 4 November 2011. Apparent half-life of direct release rate was estimated to be 346 days. The estimated total amounts of directly released ^{137}Cs was 3.6±0.7 PBq from 26 March 2011 to 26 October 2015. Simulated ^{137}Cs activities attributable to direct release were in good agreement with observed activities, a result that implies the estimated direct release rate was reasonable. Simulated ^{137}Cs activity affected off coast in the Fukushima prefecture.

$^{90}Sr/^{137}Cs$ activity ratio of stagnant water was 0.05 in the basement of the 1F NPP reactor 2 turbine building on 27 March 2011. Direct release rate of ^{90}Sr was estimated to be 1.1×10^{13} Bq/day from 26 March to 6 April 2011 using the activity ratio in stagnant water because the stagnant water released to the ocean in this period (Tsumune et al., 2012). And the temporal change of direct release rate was estimated by the measured ^{90}Sr activity adjacent to 1F NPP. Directly release rate decreased exponentially to 3.9×10^{10} Bq/day by 30 April 2011. The direct release rate was constant and decreased exponentially from 27 June to 16 December 2013. And the direct release rate was 2.9×10^{9} Bq/day by 26 October 2015. The estimated total amounts of directly released ^{90}Sr was 208 ±42 TBq.

$^{3}H/^{137}Cs$ activity ratio of stagnant water was 8.7×10^{-3} in the basement of the 1F NPP reactor 2 turbine building on 27 March 2011. Directly release rate of ^{3}H was estimated to be 1.9×10^{12} Bq/day from 26 March to 6 April 2011 and decreased exponentially by 16 April 2011. The rate was decreased exponentially with constant rate by 26 October 2015. The direct release rate was estimated to be 7.7×10^{9} Bq/day at 26 October 2015. The estimated total amounts of directly released ^{3}H was 131 ±26 TBq.

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