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Long term behavior of TEPCO FNPP1 derived radiocaesium in the North Pacific Ocean through the end of 2016: A review

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1, Two major source terms of radiocaesium to the Ocean
There are two major sources of radionuclides to the environment derived by the TEPCO Fukushima Dai-ichi Nuclear Power Plant (FNPP1) accident in 2011. The largest and earliest source of artificial radionuclide was atmospheric release from three melt down cores of FNPP1, which led to atmospheric deposition on both land and in the ocean. Total amount of atmospheric release of 137Cs was estimated to be 15.2-20.4 PBq (and same amount of 134Cs) (Aoyama et al., 2016). About 20 % of released radiocaesium fell on land and 80% of released radiocaesium fell on the ocean. Therefore 11.7-14.8 PBq of 137Cs was injected in the North Pacific as atmospheric deposition. Second largest source was the direct discharge of contaminated waters to the ocean since 26 March 2011 and peaked on 6 April 2011 (Tsumune et al., 2012). Total amount of directly released 137Cs was estimated to be 3.5 +- 0.7 PBq. A combined input to the North Pacific was therefore 15.2 - 18.3 PBq.
2, Three major pathways of FNPP1 derived radiocaesium in the North Pacific
The fastest pathway of radiocaesium might be surface. FNPP1-derived radiocaesium injected at north of Kuroshio front by atmospheric deposition and direct discharge spread eastward in surface water by the North Pacific Current across the mid-latitude North Pacific (Aoyama et al., 2016). A model simulation by Tsubono et al.(2016) also shows good agreement with the observed radiocaesium activities in the North Pacific.
The second pathway is formation of central mode water (CMW). A maximum of radiocaesium activity in June/July 2012 was observed at potential densities of 26.1–26.3 at 34 deg. N–39 deg. N along 165 deg. E, which correspond to 400 meters depth. The density is in a range of density of CMW and radiocaesium activity was higher than those in the surrounding waters, including STMW. In June-July 2015 and June 2016 at 36 deg. N–44 deg.N, 165 deg. E – 170 deg. E, we observe very week signal of FNPP1 radiocaesium, which means that subducted radiocaesium might have moved eastward from this region.
The third pathway is formation of subtropical mode water (STMW). FNPP1-derived radiocaesium injected at south of Kuroshio front by atmospheric deposition transported to southward rapidly due to formation of STMW at potential densities of 25.1–25.3. In 2015 along 165 deg. E, FNPP1 radiocaesium corresponding STMW spread entire subtropical gyre and a part of them reached 2 deg. N and recirculated in the subtropical gyre and reached Japanese coast.
3, Mass balance of FNPP1 radiocaesium in the North Pacific
134Cs inventory was estimated to be 8 PBq in surface layer in summer 2012 (Inomata unpublished). Kaeriyama et al. (2016) estimated that 134Cs inventory in STWM in 2012 was about 4 PBq. We believe that FNPP1 derived 134Cs injected in the North Pacific was 15.2 - 18.3 PBq. Therefore 134Cs inventory can be estimated 3-6 PBq in CMW at this moment based on a mass balance of FNPP1 radiocaesium.