Long-term assessment of airborne radio-cesium after the Fukushima nuclear accident: re-suspension from soil and vegetation

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The long-term effect of ^{137}Cs re-suspension from contaminated soil and vegetation due to the Fukushima nuclear accident has been quantitatively assessed using a numerical simulation, a field experiment on dust deflation flux in the contaminated area (Namie, Fukushima) and air concentration measurements inside (Namie; Ishizuka et al., 2016) and outside (Tsukuba, Ibaraki; Igarashi et al., 2015) of the area. Because the re-suspension mechanism is still unknown, by utilizing observation data both inside and outside of the contaminated area together with the 3D numerical simulation, we aimed, to the utmost extent, robust budget analysis of the re-suspension, transport, and re-deposition in the eastern part (Tohoku and Kanto regions) of Japan. Our findings are summarized as follows:

1. Optimization of the deposition parameters of a Lagrangian model for the emergency situation in March 2011, using the aircraft observation (NRA, 2012) and prescribed emission inventory (Katata et al., 2015), resulted in the dry deposition velocity of 0.1 cm/s over land and 0.04 for the collection efficiency between aerosol and hydrometeors, respectively. The optimized (or validated) deposition parameters applied for the long-term re-suspension assessment in the year 2013.
2. Using the dust deflation module (Ishizuka et al., 2016) developed on physics basis, the ^{137}Cs re-suspension from soil could account for the observed surface air concentration measured at Namie only in the cold season, while significantly underestimated by one to two orders of magnitude in the warm season. Introducing re-suspension from vegetation with the constant re-suspension coefficient 10^{-7} /h and monthly forest green area fraction could quantitatively account for the observation together with the seasonal variation. The contribution from the additional emission from the reactor buildings of FDNPP (10^6 Bq/h) was negligible throughout the year, underestimated the observed air concentration by more than three orders of magnitude at the both sites.
3. At Namie and Tsukuba, the simulated contribution of re-suspension from soil was high (0.6-0.8) in the cold season and low (0.1-0.4) in the warm season (and the rest was from vegetation, low in winter and high in summer). The contribution of the source area (where the aircraft-observed deposition exceeded 300 kBq/m^2) to air concentration at Namie was 0.8-0.9 throughout the year, while that at Tsukuba varied from 0.1 to 0.4 high in summer and low in winter.
4. The simulated total re-suspension amount for the whole region was 1.01 TBq, equivalent to 0.037% of the aircraft-observed total deposition amount, 2.68 PBq. The regional total deposition was 0.18-0.23 TBq, equivalent to 17.8-22.8% of the re-suspended amount. The spatial distribution of the estimated ground ^{137}Cs deposition decreasing rate ranged 2.2×10^{-7} - 6.6×10^{-6} /d. The first order decay for air dose rates of monitoring posts in Fukushima ranged $5.2\text{-}12.1\times10^{-4}$ /d. By subtracting radioactive decay rate, $3.0\text{-}4.2 \times 10^{-4}$ /d, the ground radioactivity decay due to run-off, decontamination, and re-suspension from air ranged $1.0\text{-}7.9\times10^{-4}$ /d. Therefore, the estimated re-suspension rate was two to three orders of magnitude lower than the decay rates due to the other processes: the re-suspension had negligible contribution to reducing the ground radioactivity.

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