Extensive study on vertical migration of ^{137}Cs in undisturbed soil after the Fukushima Dai-ichi Nuclear Power Plant accident.

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The depth distribution of ^{137}Cs is important not only for radiation protection, but also for radioecology and geoscience. Most of the deposited ^{137}Cs is adsorbed on surface soil particles and then migrates downward over time by various processes. Previous studies on depth distribution of ^{137}Cs have focused on short-term or localized areas and lacked temporal and spatial comprehensiveness. This study aims to grasp the depth distribution of ^{137}Cs in undisturbed areas over a wide area affected by the Fukushima Dai-ichi Nuclear Power Plant accident and its change with time. Additionally, uncertainties in the relaxation mass depth (β, g cm^{-2}), a parameter representing the depth distribution, and differences from the findings after the Chernobyl Nuclear Power Plant accidents and the Weapons test were evaluated.

Soil samples were collected at 84-91 locations, mainly within 80 km of 1F, during a total of 17 campaigns between December 2011 and September 2024. Soil was collected with a scraper plate, 8-9 layers to a depth of 0-10 cm. Air dose rates at 1 m above the ground were also measured at the same location using NaI scintillator. The ^{137}Cs-activity in the samples was analyzed by germanium detector (GC3020-7500SL, Canberra, Meriden, USA). The Cs depth distribution in the soil was evaluated by the depth at which 90% of deposition occurs (L_{90}) and β. To obtain β, the exponential function and the hyperbolic scant function were fitted. Samples for which both functions could not be fitted were excluded from the analysis. For samples with hyperbolic scant distribution, the deposition was further determined by a fitted function, and then an exponential approximation was assumed to calculate an effective β (β_{eff}) that satisfied both deposition and air dose rate.

The geometric mean of L_{90} increased from 2.0 cm 9 months after the accident to 5.6 cm 13.5 years after the accident. Changes in β and β_{eff} with time are shown in Figure 1. Both β and β_{eff} increased with time and was well represented by a power function (Root Mean Squared Error = 0.71 g cm^{-2}). The International Commission on Radiation Units and Measurements recommends β values depending on years after the deposition based on the findings after the Chernobyl Nuclear Power Plant accident and the Weapons test, and the β values in this study are generally lower than the recommended values.

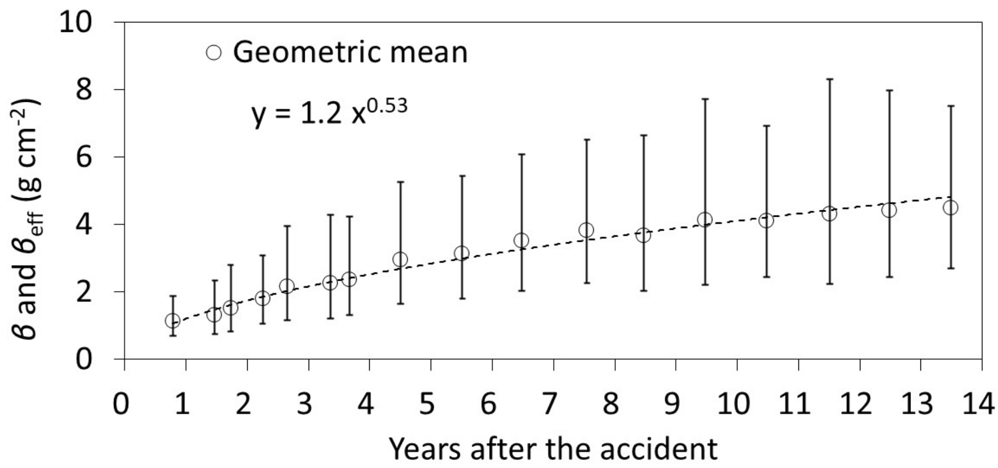

Figure 1. Increase in β and β_{eff} with time after the Fukushima Dai-ichi Nuclear Power Plant accident.