Calculation of Effective Dose Conversion Coefficient for Radioactive Cesium in Contaminated Soil by Depth

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Large area may be contaminated after nuclear power plant accident. As an emergency preparedness, it is necessary to calculate radiation dose to the workers or the public on the contaminated area. Radionuclide concentration in soil varies depending on soil depth and time due to vertical migration of the deposited radionuclides within the ground. The objective of this study was to generate dose coefficients by depth profile for ^{134}Cs and ^{137}Cs. Semi-infinite contaminated soil was simulated with MCNPX code and radiation dose was calculated with computational phantom. Absorbed dose to each organ and effective dose was calculated at 1 kBq/m^2 contaminated soil for each depth assuming soil densities ranging 0.5 - 2 g/cm^3. Radiation dose to the workers or the public on the contaminated area can be easily calculated with the generated database and depth profile of radioactive cesium in contaminated soils.

I. INTRODUCTION

Large amount of radionuclides had been released to atmosphere and deposited on the ground due to the Fukushima Daiichi Nuclear Power Plant (NPP). It led to the large radioactively contamination area. Radionuclide concentration in soil varies depending on soil depth and time due to vertical migration of the deposited radionuclides within the ground. Depth profiles of radioactive cesium in contaminated soils provide useful information for radiation protection and decontamination. Therefore, the Japan government continuously measured radioactive cesium concentration in contaminated soil by depth. According to literature, depth profiles have showed exponential distribution after Chernobyl and Fukushima NPP accident. However, radionuclide depth profiles have represented various distributions in some cases caused by remediation activities and environmental effects. For radiation protection purpose, it is necessary to calculate radiation dose to the remediation workers and the public on the area. The objective of this study was to generate dose coefficients by depth profile for ^{134}Cs and ^{137}Cs. The generated database can be used for dose assessment at contaminated area with radioactive cesium.

II. Materials and Methods

Radiation transport code, MCNPX was used to generate dose coefficients. Semi-infinite contaminated soil was simulated with the MCNPX code and radiation dose was calculated with the International Commission on Radiological Protection (ICRP) reference voxel phantoms. The radius and thickness of soil were assumed to 250 m and 1 m respectively and the radius and thickness of air were assumed to 250 m. Composition ratios were referred to International Commission on Radiation Units and Measurements (ICRU) soil type 1 and National Institute of Standards and Technology (NIST) respectively. The soil densities were assumed to 0.5 g/cm^3, 1 g/cm^3, 1.5 g/cm^3 and 2 g/cm^3. ^{134}Cs and ^{137}Cs were major contributors to radiation dose after NPP accident because it has a relatively long half-life. Therefore, ^{134}Cs and ^{137}Cs were considered in this study. To generate dose coefficients, ICRP reference voxel phantom was placed in the simulated contaminated soil. In order to consider various soil distribution, 10 cm contaminated soil was simulated as uniformly contaminated by 1 cm. After that, the absorbed dose to each organ and effective dose was calculated at 1 kBq/m^2 contaminated soil for each depth.

Ⅲ. Results and Discussion

Fig. 1 shows the absorbed dose rate to tissue or organ. The results were calculated for soil depth of 0-1 cm and 1 g/cm^3 of soil density. Bone surface received the highest radiation dose and followed by skin, salivary gland, testes, and muscle.

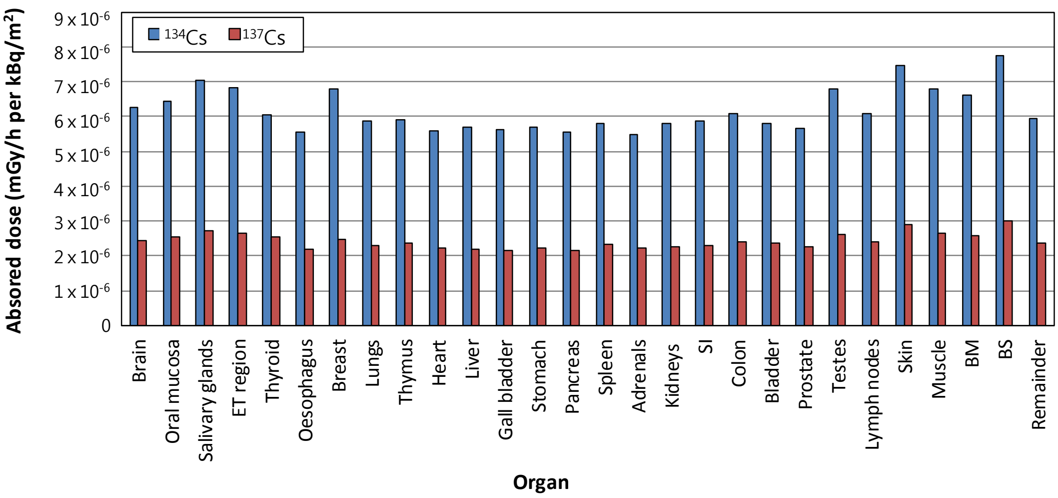

Fig. 1. Absorbed dose to tissue or organ when soil is contaminated by radioactive cesium. Contamination depth is 0-1 cm.

Table 1 shows the dose coefficients by soil depth and density. Dose coefficients of ^{134}Cs were about three times higher than dose coefficients of ^{137}Cs since higher gamma radiation yield and emitted radiation energies. The dose coefficients decreased with increasing soil density. The difference of dose coefficients increased with soil depth because the radiations emitted from the contaminated soil were attenuated.

TABLE I. Dose coefficients (mSv/h per kBq/m^2) to convert from activity concentration of ^{134}Cs and ^{137}Cs to effective dose rate

Nuclides	Density (g/cm^3)	Depth of contaminated soil away from the surface (cm)									
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
^{134}Cs	0.5	7.0E-06	5.4E-06	4.6E-06	4.1E-06	3.7E-06	3.4E-06	3.1E-06	2.9E-06	2.7E-06	2.5E-06
	1	6.2E-06	4.4E-06	3.5E-06	3.0E-06	2.6E-06	2.3E-06	2.0E-06	1.8E-06	1.7E-06	1.5E-06
	1.5	5.7E-06	3.8E-06	2.9E-06	2.3E-06	2.0E-06	1.7E-06	1.5E-06	1.3E-06	1.1E-06	9.8E-07
	2	5.3E-06	3.2E-06	2.4E-06	1.9E-06	1.6E-06	1.3E-06	1.1E-06	9.3E-07	7.7E-07	6.5E-07
^{137}Cs	0.5	2.6E-06	2.0E-06	1.7E-06	1.5E-06	1.4E-06	1.2E-06	1.1E-06	1.0E-06	9.7E-07	9.2E-07
	1	2.4E-06	1.6E-06	1.3E-06	1.1E-06	9.5E-07	8.4E-07	7.5E-07	6.7E-07	6.0E-07	5.5E-07
	1.5	2.1E-06	1.4E-06	1.1E-06	8.6E-07	7.2E-07	6.2E-07	5.4E-07	4.7E-07	4.1E-07	3.6E-07
	2	2.0E-06	1.2E-06	8.8E-07	7.1E-07	5.8E-07	4.9E-07	4.1E-07	9.3E-07	2.8E-07	2.4E-07

IV. CONCLUSIONS

Dose coefficients by contaminated soil depth were generated for ^{134}Cs and ^{137}Cs. Radiation dose to the workers or the public on the contaminated area can be easily calculated with the generated database and depth profile of radioactive cesium in contaminated soils.

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