Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 24-25, 2024

Study of indoor radioactive material paths from accidenrs

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Keywords : Pathway, Contaminant Deposition, Contamination Rate, PHITS

1. Introduction

When a serious nuclear power plant accident causes a large amount of radioactive material to leak and spread, local residents are quickly evacuated. In 2011, the Fukushima Daiichi nuclear power plant accident caused large amounts of radionuclides to accumulate across Japan, leading to evacuation orders for large areas of Fukushima Prefecture. Areas where annual cumulative doses are expected to exceed 20 to 50 millisieverts or 50 millisieverts have been designated as no-go and no-return zones, respectively, and residents have been evacuated. Decontamination activities are gradually expanding the areas where residents can return to their homes [1]. After these decontamination activities, you need to assess the radiation exposure of residents in preparation for lifting occupancy restrictions. However, the distribution and penetration pathways of radionuclides are unclear, making it difficult to accurately assess indoor and outdoor doses. These exposure prediction models require the subsurface of a residential area and the radionuclide concentration on each surface, or the ratio of the concentration on each surface to the subsurface concentration, as parameters representing the indoor and outdoor radionuclide distribution. In other words, it is important to know the extent of contamination of the ground surface and subsurface in residential areas, and it is necessary to investigate the factors that affect the distribution of radionuclides in order to investigate the generality of the indoor and outdoor radionuclide distribution. Due to the Fukushima Daiichi nuclear power plant accident, a large amount of radionuclides were released into the atmosphere, and various investigations on the distribution of radionuclides indoors and outdoors have been conducted.

2. Methods and Results

2.1 Materials to be evaluated

After the nuclear accident, various measurements of radionuclide contamination on indoor and outdoor surfaces of residential dwellings were made. The study was based on these measurements. [2,3,4 5,6,7,8].

2.2 Sampling targets

Ambient dose rates measured with a NaI(Tl) scintillation dosimeter in October and November 2015 in eight houses in Futaba and Okuma villages (hereafter referred to as A-G houses) located in the evacuation area of Fukushima Prefecture were used. Dose 1 was measured at a height of 1 m above ground level at the four corners of the exterior of the houses, dose 2 was measured at a height of 1 m above the floor in the center of the room, and dose 3 was measured at a height of 5 cm above the indoor surfaces of the floor, walls, and ceiling. Doses were measured at the center of the floor and ceiling and on surfaces around openings (defined in this paper as windows, doors, vents, air conditioner outlets and outlets) to investigate the indoor distribution of radionuclides and the main entry pathways. The air intake from these openings had been reported to be high (Murakami and Yoshino, 1983). [9] Doses around the openings 3 were measured on surfaces approximately 10 cm and 50 cm or more from each opening.

2.3 Computational Simulation Methods

To determine the contribution of soil contamination to the exposure dose and contaminated surfaces, dose rates were calculated using PHITS . A two-story virtual building with each floor measuring 12 m × 8 m × 5.5 m as shown in Fig. The thickness of the walls, roof, and floor was assumed to be 4 cm. The density and elemental composition of the walls, roof, floor, and soil were based on Furuta and Takahashi (2014, 2015).[10] Cs-137 was assumed to be uniformly distributed (=1 Bq m-2) in the following locations p(i) outdoor ground surface except under houses, p(ii) underground except under houses, and the depth profile of the concentration C described by the exponential function was given by the following equation.

A result was obtained for the ratio of dose 1 to dose 2. Dose 1 was measured at the point closest to the measurement point of dose 2. Dose 1 values varied from house to house due to differences in the amount of radionuclide deposition, and ranged from 0.83 to 15.96 μSv h-1. Since these values are much higher than the natural radiation level of 0.06 μSv h-1 in the area, it is clear that Dose 1 was caused by man-made radiation according to Minato, 2006. Therefore, the discussion in this study does not consider the effects of natural radiation. Dose 2 varied from house to house and ranged from 0.47 to 8.31 μSv h-1, with higher values for dose 2 in the same locations where dose 1 was higher inside the houses.

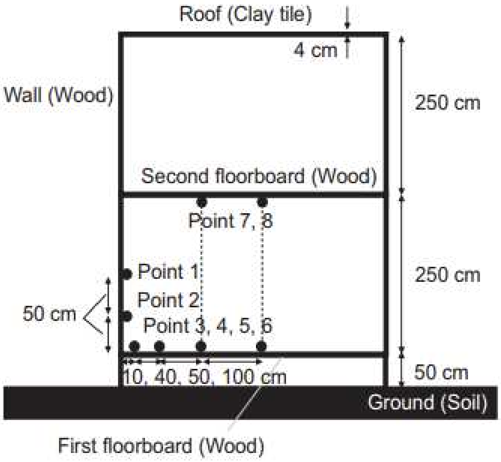

Fig. 1. Layout of the model house and dose rate evaluation points.

Table 1. Measured outdoor and indoor dose rates and the ratios of indoor to outdoor dose rate.

House	Ave. Dose (Indoor)	Ave. Dose (Outdoor)	in/out
A	2.766	5.979	0.479
B	1.789	4.029	0.455
C	6.299	15.466	0.409
D	0.666	1.201	0.567
E	0.480	1.060	0.457
F	1.083	4.523	0.243
G	1.939	5.674	0.358
H	3.329	6.734	0.507

Table 2. Calculated dose rates (nSv h^{-1}). Activity concentration of Cs-137 was set to 1 Bq m^{-2}.

Point	on ground p (i)	in ground p (ii)	on outdoor wall p (iii)	on roof p (iv)	on indoor wall p (v)	on floor p (vi)
1	0.154	0.068	0.065	0.003	0.085	0.033
2	0.16	0.066	0.065	0.003	0.084	0.047
3	0.048	0.026	0.049	0.006	0.055	0.075
4	0.03	0.013	0.026	0.007	0.025	0.08
5	0.025	0.01	0.019	0.008	0.014	0.083
6	0.022	0.009	0.013	0.01	0.009	0.087
7	0.04	0.023	0.029	0.022	0.012	0.019
8	0.039	0.021	0.016	0.026	0.009	0.021

As shown in the table, for measurements at the wall (points 1 and 2), the largest contribution to the dose rate was from radionuclides on the outdoor floor (if the radionuclides did not penetrate the floor). For measurements from the floor (points 3-6), the largest contribution was from the indoor floor. For measurements from the ceiling (points 7 and 8), the contribution from all locations was about the same..

3. Conclusions

Comparisons of post-Fukushima survey results show different levels of contamination measured on roofs compared to the ground in Fukushima and Europe.[8,6] However, because there is insufficient information to explain the causes of the differences, it is not possible to determine whether the ratio of contamination on roofs to the ground should be different for different countries and roof materials. More information on the contamination levels of indoor and outdoor surfaces in Fukushima is needed to clarify this difference..

Acknowledgement

This paper is research conducted with the support of the National Research Foundation of Korea (NRF) with funding from the government (Ministry of Science and ICT) (NRF-2020M2D2A2062571).

REFERENCES

[1] Reconstruction Agency 2016, Basic guidelines for reconstruction in response to the great east Japan earthquake in the Reconstruction and revitalization period. ⟨http://www.reconstruction.go.jp/english/topics/Laws_etc/20160527_basic-guidelines.pdf⟩(accessed 16.08.24.).
[2]Andersson, K.G., 2009. Migration of radionuclides on outdoor surfaces. In: Radioactivity in the Environment, vol. 15. Elsevier Science, pp. 107–146.
[3] Nichoison, K.W., Hedgecock, J.B., 1991. Behaviour of radioactivity fromChernobyl–weathering from buildings. J. Envrion. Radioact. 14, 225–231.
[4] Allott, R.W., Kelly, M., Hewitt, C.N., 1994. A model of environment behavior of contaminated dust and its application to determining dust fluxes and residence times. Atmos. Environ. 28, 679–687.
[5] Roed, J., 1987. Dry deposition in rural and urban areas in Denmark. Rad. Prot. Dos. 21 (1/3), 33–36.
[6] Andersson, K.G., Roed, J., Byrne, M.A., Hession, H., Clark, P., Elahi, E., Byskov, A., Hou, X.L., Prip, H., Olsen, S.K., Roed, T., 2004. Airborne Contamination in the Indoor Environment and its Implications for Dose. Risø-R-1462. Risø National Laboratory.
[7] Andersson, K.G., Roed, J., Fogh, C.L., 2002. Weathering of radiocesium contamination on urban streets, walls and roofs. J. Environ. Radioact. 62, 49–60.
[8] Yoshimura, K., Watanabe, T., Kurikami, H., 2020. Vertical and horizontal distributions of Cs on paved surfaces affected by the Fukushima Dai-ichi Nuclear Power Plant accident. J. Environ. Radioact. 217, 106213.
[9] Murakami, S., Yoshino, H., 1983. Investigation of air-tightness of houses. Archit. Inst. Jpn. 325, 104–115.
[10] Furuta, T., Takahashi, F., 2015. Study of radiation dose reduction of buildings of different sizes and materials. J. Nucl. Sci. Technol. 52 (6), 897–904.