Derivation of the Radioactivity Index for Consumer Goods Containing NORM

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1. Introduction

To protect the public from natural radioactive materials, the "Act on safety control of radioactive rays around living environment" was established in Korea. Some consumer goods to promote health such as anion bracelets, necklace and mats contain naturally occurring radioactive material (NORM). Some of them can cause problems because of high radioactivity. In the regulations, there is an annual effective dose limit of 1mSv for products, but the activity concentration limits and radioactivity index for products is not established yet. Although there are few researches for consumer goods containing NORM in foreign countries, in Japan, for the consumer goods in contact with human bodies, they have guidelines of quantity of radioactivity as shown in Table I.

Table I: Quantity of radioactivity that reaches 1mSv/year in the case of use in contact with human bodies

	Unit	Thorium	Uranium
Exposure dose	mSv/y	1.0	1.0
Conversion factor	mSv/h/Bq	9.60E-09	1.30E-08
Quantity of radioactivity	Bq	11,891	8,781
Duration of use	H/y	8,760	8,760
Distance from the product	M	In contact with human bodies	In contact with human bodies

2. Methods and Results

To derive the activity concentration limits for consumer goods and to suggest the radioactivity index, it is necessary to model the consumer goods considering radiation irradiation environment.

2.1 Radiation Irradiation Scenario

For the consumer goods in contact with or close to human bodies, because they have a variety of shape, size and usage quantities, it is very difficult to assume a typical scenario for radiation irradiation. In this study, we assumed a "small room model" surrounding the ICRP reference phantom as shown in Fig.1 to simulate the consumer goods in contact with the human bodies. From the "room model" to simulate the building materials [1], we developed the idea to simulate the consumer goods as similar ways.

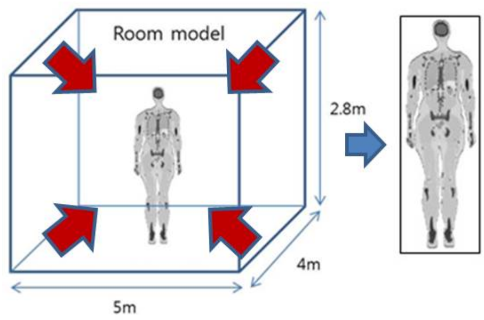

Fig. 1. Small room model for consumer goods

From the "room model" to simulate the building materials [1], we developed the idea to simulate the consumer goods as similar ways. We reduced from the room size to phantom size and assumed the density of 2.35 g/cm^3 as concrete. Using the Monte Carlo code MCNPX, we evaluated the effective dose rate for the ICRP reference male in a small room model. Because the consumer goods have a variety of usage quantity, we calculated the specific effective dose rate according to the usage quantity using the gamma energies and emission probabilities as shown Table II. The modeled radioactive sources are assumed to be uniformly distributed in walls and both ^{238}U and ^{232}Th series are assumed to be in secular equilibrium.

Table II: Averaged gamma energies and emission probabilities used in simulation

Radionuclide	Energy(keV)	Emission Probability
^{238}U	845	1.98
^{232}Th	894	2.61
^{40}K	1461	0.106

2.2 Derivation of the Activity Concentration Limits

From the simulation, we calculated the effective dose rate for uranium, thorium and potassium as shown in Table III. Considering the specific effective dose rate, we calculated the activity concentration limits using Equation (1).

$$1(mSv/year) = (SDR_x \times A_x) \times AUT \quad (1)$$

Where, SDR_x is specific effective dose rate for the radionuclide x (Sv/h per Bq/kg). A_x is the activity concentration limit of nuclide x (Bq/kg) and AUT is average usage time (h/year). Conservatively, we assumed the average usage time of 8760 h and the activity concentration limits A_x for uranium, thorium and potassium are shown in Fig 2, 3 and 4.

Table III: Specific effective dose rate for consumer goods

Thickness (cm)	Usage quantities (kg)	Specific effective dose rate (Sv/h per Bq/kg)		
		^{238}U	^{232}Th	^{40}K
0.001	0.075	7.67E-14	1.07E-13	6.85E-15
0.01	0.75	7.69E-13	1.07E-12	6.86E-14
0.02	0.82	8.42E-13	1.17E-12	7.51E-14
0.03	1.57	1.61E-12	2.21E-12	1.44E-13
0.04	2.32	2.38E-12	3.31E-12	2.12E-13
0.05	3.07	3.15E-12	4.38E-12	2.81E-13
0.1	6.83	7.01E-12	9.74E-12	6.24E-13
0.14	10.76	1.10E-11	1.53E-11	9.80E-13
0.15	38.05	3.85E-11	5.34E-11	3.40E-12
0.91	70.17	6.92E-11	9.59E-11	6.10E-12
1	77.34	7.57E-11	1.05E-10	6.67E-12

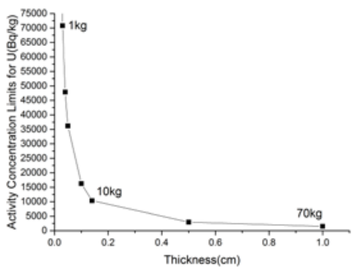

Fig. 2. Activity concentration limits for ^{238}U (Bq/kg)

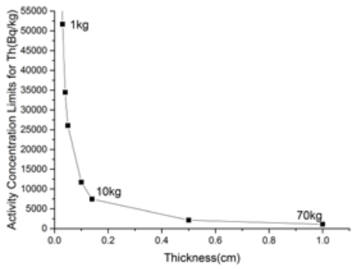

Fig. 3. Activity concentration limits for ^{232}Th (Bq/kg)

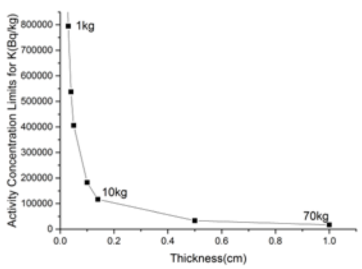

Fig. 4. Activity concentration limits for ^{40}K (Bq/kg)

2.3 Suggestion of the Radioactivity Index

The radioactivity index using activity concentration limits are expressed as shown equation (2) introduced in the RP112 and STUK report [2, 3]. In other words, the indexes I for the consumer goods are less than 1, the annual dose limit of 1mSv is satisfied.

$$I = \frac{C_U}{A_U} + \frac{C_{Th}}{A_{Th}} + \frac{C_K}{A_K} \quad (2)$$

Where, C_u, C_{Th} and C_K are the activity concentration of ^{238}U series, ^{232}Th series and ^{40}K in consumer goods (Bq/kg), respectively. Using the results obtained in section 2.2, for example, we can suggest the radioactivity index as following formulas (3) and (4).

$$I = \frac{C_U}{1600} + \frac{C_{Th}}{1100} + \frac{C_K}{18000} (< 70kg) \quad (3)$$

$$I = \frac{C_U}{16000} + \frac{C_{Th}}{11000} + \frac{C_K}{180000} (< 7kg) \quad (4)$$

In other words, as shown equation (3) and (4), after the consumer goods classified into bulk (less than 70kg) and small quantities (less than 7kg), the radioactivity indexes can be applied.

3. Conclusions

To regulate the NORM in consumer goods, it is necessary to derive activity concentration limits corresponding to the annual limits of 1mSv. In this research, we calculated the activity concentration limits according to the usage quantities of consumer goods. Using these results, it is possible to suggest several radioactivity indexes to apply to a lot of consumer goods.

REFERENCES

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