A Review of Equilibrium Factors of Indoor Radon and Thoron for Radiation Dose Assessment

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1. Introduction

Radon is one of the natural radionuclides present in natural environment and is colorless, odorless radioactive gas. There is a growing social concern in radon because of its large contribution to radiation dose and its common presence.

However, compared with the growing social concern, the methodology of evaluating the radiation dose for indoor radon has not been clearly established in Korea. Therefore, to evaluate the radiation dose due to the inhalation of radon, it is necessary to study evaluation model and methodology.

International organizations such as UNSCEAR, NCRP, and ICRP have evaluated radiation doses due to radon by considering the major exposure factor to indoor radon concentration. The equilibrium factor is one of the major exposure factors. To evaluate the radiation dose, it is required to convert indoor radon concentration to equilibrium equivalent concentration (EEC) by using equilibrium factor. That can be varied depending on the environmental conditions and the measurement methods, which means that the radiation dose due to indoor radon may vary widely.

The objective of this study was to investigate major factors influencing equilibrium factor, one of the major exposure factors, were investigated. In addition, the case of foreign countries considering those factors was investigated. Based on this, the direction of setting equilibrium factor in the future was suggested.

2. Equilibrium Factor and Major Influence Factor

2.1 Concept of Equilibrium Factor

In closed systems, radon with long half-life and progeny with short half-life are in equilibrium. However, the general space is open system. Therefore, to evaluate the radiation dose due to radon gas, it is necessary to uniformize the concentration of the equilibrium state, the equilibrium equivalent concentration of radon. The equilibrium factor is applied to convert the measured radon gas concentration C_{Rn} into the equilibrium equivalent radon concentration EEC_{Rn}. The equilibrium factor F is defined as follows.

$$F = \frac{EEC_{Rn}}{C_{Rn}}$$

The value of the equilibrium factor can vary depending on the environmental conditions and the measurement method. In addition, the value can also vary depending on the distance from the source to the detector and the measurement period (e.g. short term or long term).

2.2 Equilibrium Factor of Radon (Rn-222)

The equilibrium factor of radon and thoron proposed by UNSCEAR was derived under limited conditions[1]. Those values were derived from short-term continuous measurements. However, the concentration of radon varies with day and season. Therefore, the accurate equilibrium factor derivation requires long-term measurement to fully reflect changes in day and season. The Figure 1 shows the results obtained by short-term measurements and long-term measurements of radon equilibrium factors in worldwide[2].

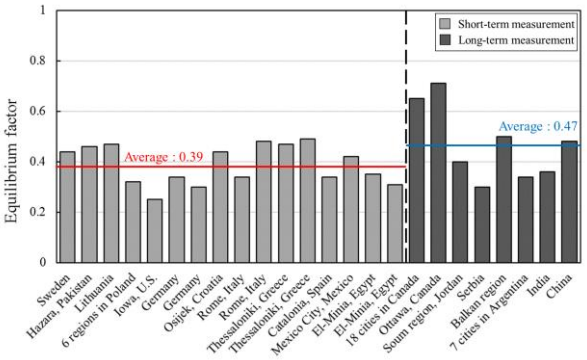

Fig. 1. Measurement results of radon concentration and radon equilibrium factor in dwellings in worldwide location

2.3 Equilibrium Factor of Thoron (Rn-220)

In the case of thoron, little research has been done on equilibrium factors compared to radon. Therefore, there are few short-term and long-term measurement results derived from large-scale surveys. Table 1 shows one of the results of the long-term measurements of the equilibrium factor of the thoron on the wall[3].

Table I: Indoor thoron and its progeny concentrations, EEC and equilibrium factor measured in dwellings

	C_{Tn} (Bq/m^3)	EETC	F_{Tn}
Minimum	9	0.3	0.0001
Median	138	0.9	0.006
Maximum	479	2.7	0.077

On the other hand, for the case measured in the USDOE Fernald site in the United States, an indoor thoron equilibrium factor of 0.04 was derived based on the data measured over two years[4].

The equilibrium factor may vary depending on the point of concentration measurement of radon and thoron. Especially, unlike radon, whose half-life is 3.8 days, the half-life of the thoron is much shorter as 55.6 seconds. Because of the short half-life, the gas under the soil can not survive long enough to get into the building in most situations and accumulate a significant amount of indoor air.

According to the calculation method proposed by the ICRU, the concentration of the thoron should be reduced to less than 1% if it is separated by more than 1 m from the wall[5]. However, in actual measurement cases, there was a case that thoron concentration was reduced to 10 to 50%. A study by Harley et al has shown that there is no difference in the thoron concentration at the point of separation between 0.5 and 2 m from the bottom (source)[4].

3. Review of Equilibrium Factor and Major Influence Factor

In order to derive the appropriate equilibrium factor for the radon and thoron, long-term measurements should sufficiently reflect day and seasonal changes in indoor concentration. According to the above results, the short-term measured equilibrium factor of radon was 0.39 and the long-term equilibrium factor was 0.47. The short-term equilibrium factor was similar to the UNSCEAR recommendation (0.4), but the long-term result was slightly higher than the UNSCEAR recommendations.

In the case of thoron, the equilibrium factor of 0.02 is generally recommended. However, the results of long - term measurements were in the range of 0.006 to 0.04. Various case of the overseas showed that the concentration of thoron decreased sharply within short distance. However, there were some cases that the results were evenly distributed at a distance more than a certain distance from the source. Therefore, the equilibrium factor of the thoron should be set in consideration of the measuring time and positional dependency.

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4. Conclusions

In this study, the major factors affecting the equilibrium factor were investigated. In general, radon and thoron have a variability of the equilibrium factor for the measurement period. Therefore, sufficient consideration should be given to the measurement period in selecting the equilibrium factor.

In the case of thoron, the research on the variability of the equilibrium factor according to the measurement point is relatively insufficient. Therefore, more studies are necessary to set equilibrium factor.

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