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THE STUDY OF THORON AND RADON PROGENY CONCENTRATIONS IN DWELLINGS IN JAPAN

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Abstract — This paper aims to make a comparison of different concentrations of thoron (^{220}Rn) progeny and radon (^{222}Rn) progeny in different kinds of dwellings. The potential alpha energy concentrations and the effective dose equivalent caused by thoron and radon progeny, respectively, have also been estimated. The measurements were carried out in 23 dwellings. The results indicate that thoron progeny concentrations indoors might be strongly affected by the type of building material used. Traditional Japanese buildings made with mud may have high thoron progeny concentrations of about 3.52 Bq.m^{-3} and a concentration ratio of thoron progeny to radon progeny of about 0.5, whereas in concrete dwellings thoron progeny concentrations are about 0.72 Bq.m^{-3} and the concentration ratio of thoron progeny to radon progeny is about 0.1. The annual effective dose equivalent of thoron progeny is 1.23 mSv in mud dwellings and 0.25 mSv in concrete dwellings.

INTRODUCTION

In recent years, many studies on radon (^{222}Rn) and its progeny in mines and in dwellings have been performed. Studies on the levels of thoron (^{220}Rn) and its progeny and the biological effects from inhalation of these nuclides are few. There are few studies on the sources of indoor thoron in Japan. The purpose of this study was to make a primary investigation of the different concentration levels of thoron progeny and radon progeny in different kinds of building materials.

MEASURING APPARATUS

The apparatus that was used throughout the investigation was a monitor with a fixed filter holder which can collect radon and thoron progeny on the filter by sampling air with a pump[1]. The pore size of the cellulose nitrate membrane filter used was 0.8 μm, and the diameter was 37 mm (ADVANTEC, Toyo Roshi Kaisha Ltd., Japan). The alpha rays emitted from radon and thoron progeny may be counted by a ZnS(Ag) detector. As radon progeny decay faster than thoron progeny because of the differences in half-life, the concentrations of radon and thoron progeny can be calculated by using the counts of radon and thoron progeny derived from the decay figure over 12 hours counting after sampling as shown in Figure 1. The sampling time of the survey was 58 min, and measurements continued for at least 4 days at each location. The position of the apparatus in dwellings was about 2 m from a wall.

THE GENERAL CLASSIFICATION OF DWELLINGS IN JAPAN

Buildings or dwellings are generally classified by frame construction and building materials. In Japan dwellings can be classified by frame construction as timber frame, concrete frame and steel frame; in concrete frame there are reinforced concrete and concrete brick. Dwellings can also be classified by building materials as conventional construction and pre-fabricated construction. As shown in Table 1, most of the dwellings in Japan are timber frame. Radon and thoron progeny concentrations indoors may be strongly affected by the building materials of the dwelling. From Table 1, it can be seen that the building materials in Japan now are mainly mud or new building materials like plaster-board and concrete. The investigations were made around Nagoya city, in mid Japan. Four dwellings made with mud, four dwellings made with new building materials, and 15 dwellings made with reinforced concrete were tested.

RESULTS AND DISCUSSION

The survey of radon and thoron progeny concentrations inside dwellings made from different building materials was carried out from December 1988 to April 1991. During the 2 years 23 places were measured in all and some of the places were measured many times during the different seasons of the year. The diurnal variation was also investigated.

The results from one test dwelling given in Figures 2 and 3 show that for both the seasonal variation and the diurnal variation of thoron there is the same trend with radon. As with radon, the seasonal variation of thoron should be considered when the annual effective dose equivalent is calculated. Rather more detailed work on this topic is needed in the future.

Radon and thoron progeny concentrations in dwellings made from different kinds of building materials are shown in Table 2. It can be seen that the dwellings made from mud and concrete had nearly the same level of radon concentration, which was higher than that of the dwellings made from new building materials. As for thoron progeny concentrations, the dwellings made from mud had the highest level, and the ratio of thoron progeny to radon progeny was the highest too, at nearly 0.5. The concentrations of radon and thoron progeny indoors were generally dependent on the exhalation rates of radon and thoron diffusing from building materials into the room and the ventilation conditions of dwellings. Practical measurements of the exhalation rates of radon and thoron from different kinds of building materials and a study of the porosity of materials are needed in the future. The ^{238}U and ^{232}Th contents in different kinds of building materials were measured with a NaI (Tl) scintillator[2]. The concentrations of ^{238}U and ^{232}Th in the building materials mud and concrete were nearly the same, about 2.46 ± 0.25 ppm and 8.78 ± 0.11 ppm, respectively, but for new building materials the contents were a little lower for both ^{238}U and ^{232}Th.

LUNG DOSE EVALUATION

When the progeny atoms associated with either thoron or radon are inhaled, a major fraction of the activity is removed from the air stream by impaction or diffusion processes and is retained on the interior surfaces of the airway passages. Those atoms not removed will decay on the surfaces of the airways, with the major fraction of the radiation dose associated with the alpha particles emitted by ^{218}Po (6.00 MeV) and ^{214}Po (7.69 MeV) for the ^{222}Rn series, and ^{212}Bi (6.05 and 6.09 MeV) and ^{212}Po (8.78 MeV) for the ^{220}Rn series. The concept of the potential alpha energy, in terms of working levels, has been widely used as a measure of environmental concentrations of radon progeny in indoor air and has been extended to include thoron progeny as well. WL is represented by a combination of short-lived radon and thoron progeny in 1 l of air that will result in the emission of 1.3×10^5 MeV of potential alpha energy from the radioactive decay of the radon or thoron progeny.

$$1 \text{ WL} = 1.3 \times 10^5 \text{ MeV.l}^{-1}$$
$$= 3700 \text{ Bq.m}^{-3} \text{ (100 pCi.l}^{-1}\text{) for radon progeny}$$
$$= 275 \text{ B.qm}^{-3} \text{ (7.43 pCi.l}^{-1}\text{) for thoron progeny}$$

The potential alpha energy concentration (PAEC) in air can be calculated separately for the radon progeny as PAEC (radon) and for the thoron progeny as PAEC (thoron). Table 3 shows the results of the survey. It can be seen that the PAEC of thoron may be higher than that of radon even though the activity concentration of radon is higher. The PAEC of thoron progeny of traditional Japanese dwellings made with mud may be rather high; about four times that of radon progeny.

Adopting the dose conversion factors for radon and thoron proposed by UNSCEAR in 1982 where

$$\text{radon: } H^{radon} = X^{radon} \times (8.76 \times 10^3) \times 8.7 \times 10^{-6}$$

$$\text{thoron: } H^{thoron} = X^{thoron} \times (8.76 \times 10^3) \times 40 \times 10^{-6}$$

the annual effective dose equivalent of radon progeny and thoron progeny could be calculated as shown in Table 4. In the two equations above, the values of X^{Radon} and X^{thoron} are the average concentration of Radon or thoron in different kinds of buildings throughout the survey. The results suggest that in traditional Japanese dwellings made with mud the radiation exposure caused by thoron progeny may be the main source.

CONCLUSIONS

The thoron progeny concentration indoors is strongly affected by the type of building material used. The mean concentration ratios (thoron progeny (thoron-p)/radon progeny (thoron-p)) were 0.10 for concrete, 0.50 for mud and 0.37 for new building materials. In terms of PAEC, the PAEC of thoron can be higher than that of radon even though the activity concentration of radon is higher. The mean PAEC ratios (thoron-p/radon-p)

Table 2. Radon and thoron progeny concentrations in dwellings made with different building materials.

Types of dwelling materials	Number of places	Concentrations* ($Bq.m^{-3}$)		Ratio (thoron-p/radon-p)
		thoron progeny	radon progeny	
Concrete	15	0.72 ± 0.24	9.99 ± 5.18	0.10 ± 0.07
Mud	4	3.52 ± 2.48	11.32 ± 9.97	0.50 ± 0.20
New building material	4	1.72 ± 0.12	5.57 ± 3.20	0.37 ± 0.29

Period of measurement: December 1988 to April 1991.
Measurement times: 1–8 times, individually.
* Mean ± SD.

were 4.18 for mud, 0.97 for concrete and 4.14 for new building materials. The contribution from thoron progeny was a significant fraction of the total lung exposure; in concrete the mean dose ratio (thoron-p/radon-p) was 0.33, in the other two cases the mean dose ratio was 1.43. Both the seasonal variation and the diurnal variation of thoron show the same trend with radon.

REFERENCES

1. Shimo, M. and Ikebe, Y. *A Continuous Measuring Apparatus Using Filter-Sampling Technique for Environmental Radon Daughters*. Res. Lett. Atmos. Electr. 4, 63-70 (1984).
2. Minato, S. *A Response Matrix of a 3" φ × 3" NaI(Tl) Scintillator for Environmental Gamma Radiation Analysis*. Report No. 12 (Government Industrial Research Institute, Nagoya) (1978).