AN ATTEMPT TO EVALUATE DOSE EQUIVALENT DUE TO THE INHALATION OF ^{222}Rn AND ITS PROGENY IN INDOOR AIR

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INTRODUCTION

An attempt to evaluate alpha dose equivalent given by inhaled ^{222}Rn and its daughter nuclides has been made based on the measured concentrations of ^{222}Rn and its progeny in indoor air and the estimated equilibrium factor between the parent and daughter nuclides. Three different dosimetric lung models were used for the evaluation of the dose equivalent, and a brief comparison was made.

MEASUREMENT

1) ^{222}Rn Concentration

An activated charcoal canister of 10 cm diameter × 2.85 cm height, which contains 70 ± 1 g of 6 × 16 mesh charcoal powder, was used for collecting ^{222}Rn in indoor air by adsorption process for a period of certain time interval. Concentration of ^{222}Rn in the air was determined by gamma-ray spectrometry using a 3″ ϕ ×3″ cylindrical NaI(Tl) detector that detects 242, 295 and 352 keV photons emitted from ^{214}Pb , and 609 keV from ^{214}Bi, both of which are the equilibrated daughter nuclides of ^{222}Rn in the canister. Calibration factors(CF) for the canister were determined with the aid of a reference canister that contains a uniformly distributed known amount of equilibrated ^{226}Ra. The humidity correction factor for the CF were deduced through a series of appraisal test for the water adsorption characteristics of the charcoal canister. CF for ^{222}Rn concentration in the air was obtained by the calibration of the canister exposed in a Rn-Chamber containing ^{222}Rn of known concentration.

The measurements of the ^{222}Rn concentration in indoor air were carried out in a laboratory room of the C. N. University where average relative humidity was maintained to be 32±2 % during the course of the measurement. Five measurements for 24 hrs and 72 hrs periods, respectively, were performed, and in each measurement 3 canisters were exposed to the indoor air. Resultant mean concentration of ^{222}Rn in the room was found to be (40.0 ± 1.9) Bq · m^{-3}.

2) ^{222}Rn Daughter Concentration and Equilibrium Factor

In order to determine the equilibrium factor, F, between the concentrations of ^{222}Rn and its progeny in the indoor air, a series of α-spectrometry was performed for the air particulate collected on a membrane filter of 47 mm diameter with 0.22 μm pore by use of an ion implanted Si detector of effective diameter of 24 mm. As the result of the spectrometry the concentrations of α-emitting daughters, ^{218}Po and ^{214}Po, were obtained. And the F is determined by[1)]

$$F = \sum_i a_i F_i \tag{1}$$

where $a_i = k \cdot (\frac{E_{p,i}}{\lambda_i})$, $F_i = (\frac{C_i}{C_{Rn}})$, and $E_{p,i}$ and λ_i are potential α-energy concentration and decay constant of ith daughter nuclide. C_i and C_{Rn} are the concentrations of ith daughter and that of ^{222}Rn in the air, respectively. k is a constant that depends on the used system of units.

Thus determined overall mean F in the room where the measurements were performed was 0.36 ± 0.12. Using this value of F the equilibrium equivalent concentration(EEC) of ^{222}Rn in the indoor air was determined to be (14.4 ± 1.9) Bq · m^{-3}.

ASSESSMENT OF THE DOSE EQUIVALENT

With the value of the F or EEC refered above the potential α-energy concentration, E_p, is estimated by[2)]

$$E_p = \frac{F \cdot C_{Rn}}{1.78 \times 10^8} \qquad (J \cdot m^{-3}) \qquad (2)$$

to be $(80.8 \pm 10.4) \times 10^{-9}$ $J \cdot m^{-3}$,

By use of the presumed mean breathing rate of 1.2 $m^3 \cdot h^{-1}$ and 0.75 $m^3 \cdot h^{-1}$ for occupational and public exposures, respectively, the potential α-energy intakes, I_p, can be estimated to be $(97.0 \pm 12.5) \times 10^{-9}$ and $(97.0 \pm 12.5) \times 10^{-9}$ $m^3 \cdot h^{-1}$, respectively, using the equation[2)]

$$I_p = B \cdot E_p \qquad (3)$$

where B is the mean breathing rate in $m^3 \cdot h^{-1}$.

It was attempted to evaluate the regional and total lung dose equivalent rate given by the inhalation of ^{222}Rn daughters in the indoor air based on the data mentioned above and by adopting three different dosimetric lung models, namely, Jacobi-Eisfeld(J-E), James-Birchall(J-B), and ICRP models, which appeared in the Table 1 of the reference 2 and the Table 2.9 of the reference 3. The dose equivalent rates were evaluated for two target tissues, the basal cell layer in the tracheo-bronchial(T-B) region and the epithelium in the pulmonary(p) region, in addition to the total lung dose. In this estimation the unattached fraction, f_i , of the ^{222}Rn daughters, which is given by

$$f_i = \frac{E^u{}_p}{F \cdot C_{Rn}} \quad \text{or} \quad E^u{}_p = F \cdot C_{Rn} \cdot f_i \qquad (4)$$

where E_p^u is the potential α-energy concentration of unattached ^{222}Rn daughter nuclide in $J \cdot m^{-3}$, was used. The results obtained by use of f_i values of 0 and 0.05 are summarized in Table 1. With an assumption of an occupancy factor of 0.8, the annual effectived dose equivalent due to the inhalation of ^{222}Rn and its progeny is also assessed and summarized in Table 2.

COMPARISON OF THE MODELS

A brief comparison in regard to the dose equivalent rate assessed by the ICRP model in the case of occupational exposure reveals that the T-D doses by the J-E and J-B models, in general, shown to be larger, except for f_i = 0, while P dose and total lung dose by both models appeared to be much smaller. Those evaluated by the J-E and J-B models were 0.65 ~ 0.70 and 0.25 ~ 0.26 times that obtained by the ICRP model, respectively.

The annual dose equivalents given by the ^{222}Rn daughters and the total lung dose estimated by the J-E model nearly coincide with(for f_i = 0) or slightly larger (for f_i = 0.05) than those given by the ICRP model, while those estimated by the J-B model for f_i = 0 are 0.7 times those by the ICRP model and 1.6 times the ICRP for f_i = 0.05. As a summary, it may be said that the J-E model looks closer to that of the ICRP than the J-B model for the evaluation of radon dose in the occupational exposure.

CONCLUDING REMARK

Through this study it was reconfirmed that the dose due to the inhalation of ^{222}Rn and its progeny in the air comes mainly from the daughter products with negligible contribution of ^{222}Rn itself. The respiratory organ dose given by the daughter products appeared to be region dependent, and T-D dose increases with unattached fraction of the progeny, while P dose decreases with the fraction.

Table 1. Regional and total lung dose equivalent due to the inhalation of ^{222}Rn daughters based on three different dosimetric lung models.

Region	Breathing rate($m^3 \cdot h^{-1}$)	Unattached fraction(f_i)	Mean dose equivalent rate ($nSv \cdot h^{-1}$)		
			J-E Model*	J-B Model*	ICRP Model
T-B	1.2	0	1746.0 ± 225.0	1358.0 ± 175.0	1455.0 ± 187.5
		0.05	2570.5 ± 331.3	4074.0 ± 525.0	1940.0 ± 250.0
	0.75	0	969.6 ± 124.8	969.6 ± 124.8	not evaluated
		0.05	1272.6 ± 163.8	1515.0 ± 195.0	
P	1.2	0	504.4 ± 65.0	194.0 ± 25.0	776.0 ± 100.0
		0.05	479.2 ± 61.8		737.2 ± 95.0
	0.75	0	363.6 ± 46.8	121.2 ± 15.6	not evaluated
		0.05	345.4 ± 44.5	115.1 ± 14.8	
Total (m=1kg)		0	679.0 ± 87.5	not evaluated	970.0 ± 125.0
		0.05	693.6 ± 89.4		989.4 ± 127.5

* J-E Model : Jacobi-Eisfeld Model J-B Model : James-Birchall Model

Table 2. The annual effective dose equivalent(μSv) due to the inhalation of ^{222}Rn and its daughters based on three different dosimetric lung models

Nuclide*	Breathing rate ($m^3 \cdot h^{-1}$)	Unattached fraction(f_i)	Annual effective dose equivalent(μSv)**		
			J-E model	J-B model	ICRP model
RnD	1.2	0	946.2 ± 98.5	652.6 ± 74.3	938.1 ± 89.4
		0.05	1282.3 ± 141.7	1794.6 ± 221.0	1125.7 ± 112.5
	0.75	0	560.6 ± 56.0	458.7 ± 52.9	not evaluated
		0.05	680.3 ± 71.4	685.4 ± 82.2	
Rn			50.5 ± 21.0		
Total	1.2	0	996.7 ± 100.7	703.1 ± 77.2	988.6 ± 91.8
		0.05	1332.8 ± 143.2	1845.1 ± 222.0	1176.2 ± 114.4
	0.75	0	611.1 ± 59.8	509.2 ± 56.9	not evaluated
		0.05	730.8 ± 74.4	735.9 ± 84.8	

* RnD : ^{222}Rn daughters
Rn : ^{222}Rn

** Effective dose equivalent

$H_E = W_{TB}H_{TB} + W_P H_P$

where W_{TB}, W_P : weighting factor of T-B and P region; 0.06, 0.06

H_{TB}, H_P : Effective dose of T-B and P region

REFERENCES

1) W. Jacobi and K. Eisfeld ; GSP Rept. S-623, Gesellschaft für strahlen und Umweltforschung mbH. München (1980) (after reference 2)

2) ICRP Publ. 32, Pergaman Press, Oxford (1981)

3) NEA/OECD ; Dosimetric Aspects of Exposure to Radon and Thoron Daughter Products, OECD (1983)