ON THE REDUCTION OF ^{222}Rn EXHALATION FROM ^{226}Ra-RICH WASTES BY COVERING OF SOIL

Y. IKEBE

Department of Nuclear Engineering, School of Engineering, Nagoya University, Chikusa-ku, Nagoya 464-01, Japan

ABSTRACT

The reduction effect for Rn-222 exhalation from a Ra-226 containing wastes by covering of ordinary soil is calculated. Although the concentration profile of radon in the soil for two layer model is quite different from that for three layer model, exhalation rates are not so much differ between the two models. It is shown that the effective diffusion coefficient of the soil is very effective for radon exhalation.

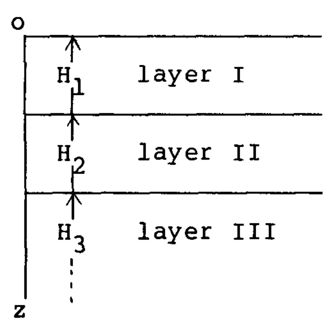
INTRODUCTION

Recently, concern of peoples about ennvironmental radon is increasing gradually. In some occasions, we shall have to reduce the activity level in air of radon exhaled from wastes such as uranium tailings, excavated Ra-rich soil from various kinds of mine, and so on. In order to reduce the Rn-222 exhalation from such wastes, a covering of normal soil upon the wastes may be practical and useful.

In this paper, the reduction effect for Rn exhalation from wastes by covering of normal soil is evaluated by calculation using various soil parameters such as Ra-226 content, Rn escape-to-production ratio, air ratio, and effective diffusion coefficient of Rn.

MODEL

First, we consider two layer model: First layer is ordinary soil of thickness H_2. Second layer is wastes of thickness $H_2=\infty$. Under steady state conditions, the diffusion of radon through soil to surface can be expressed in each layer by the diffusion equation[1,2]



$$D \frac{d^2C}{dz^2} + a - \lambda C = 0$$

where C(z) is the concentration of radon atoms in soil air (atom·cm^{-3} of soil air), a is the supply rate of radon atom to soil air (atom·cm^{-3} of soil air·s^{-1}), λ is the decay constant of radon (s^{-1}), and D is the effective diffusion coefficient of radon in soil air (cm^2·s^{-1}).

If we denote δ is the escape-to-production ratio of radon (-), n is the air ratio (=air volume)/(total volume of soil), (-), A is the Ra-226 activity (Bq·cm^{-3} of soil), C_s is the concentration of radon atoms existing in soil air (atom·cm^{-3} of soil), then $C_s=nC(z)$ and $a=\delta A/n$.

The boundary conditions are given by $C_1(0)=0$, $n_1C_1(H_1)=n_2C_2(H_1)$, $(C_{s1}(H_1)=C_{s2}(H_1))$, $\lambda C_2(\infty)=a_2$,

and $$D_1\left(\frac{dC_{s1}}{dz}\right)_{H_1}=D_2\left(\frac{dC_{s2}}{dz}\right)_{H_1}.$$

The solutions are given by:

At first layer $$C_1(z)=A_1\exp\left(\sqrt{\frac{\lambda}{D_1}}z\right)+B_1\exp\left(-\sqrt{\frac{\lambda}{D_1}}z\right)+\frac{a_1}{\lambda}$$

where $$A_1=\left\{\frac{a_1}{\lambda}\left(1-\sqrt{\frac{D_1}{D_2}}\right)\exp\left(-\sqrt{\frac{\lambda}{D_1}}H_1\right)-\frac{n_1a_1-n_2a_2}{\lambda n_1}\right\}/$$
$$\left\{\left(1+\sqrt{\frac{D_1}{D_2}}\right)\cdot\exp\left(\sqrt{\frac{\lambda}{D_1}}H_1\right)-\left(1-\sqrt{\frac{D_1}{D_2}}\right)\exp\left(-\sqrt{\frac{\lambda}{D_1}}H_1\right)\right\}$$

$$B_1=-\left(A_1+\frac{a_1}{\lambda}\right).$$

At second layer $$C_2(z)=B_2\exp\left(-\sqrt{\frac{\lambda}{D_2}}z\right)+\frac{a_2}{\lambda}$$

where $$B_2=-\frac{n_1}{n_2}\sqrt{\frac{D_1}{D_2}}\exp\left(\sqrt{\frac{\lambda}{D_2}}H_1\right)\left[\left\{\exp\left(\sqrt{\frac{\lambda}{D_1}}H_1\right)\right.\right.$$
$$\left.\left.+\exp\left(-\sqrt{\frac{\lambda}{D_1}}H_1\right)\right\}A_1+\frac{a_1}{\lambda}\exp\left(-\sqrt{\frac{\lambda}{D_1}}H_1\right)\right].$$

The exhalation rate, E(atom.cm^{-2}s^{-1}), at the surface is given by

$$E=-n_1D_1\left[\frac{dC_1}{dz}\right]_{z=0}=-n_1D_1\left(A_1\sqrt{\frac{\lambda}{D_1}}-B_1\sqrt{\frac{\lambda}{D_1}}\right)$$

Secondly, three layer model was treated, in which the third layer corrsponds to the basic ground ($H_3=\infty$). The formulae of $C_3(z)$ and E were obtained analytically using similar boundary conditions to those used for the two layer model.

CALCULATION

The parameters used for the present work are $D_1=D_2=D_3=D=0.054$, 0.054/10, 0.054/100, $n_1=n_2=n_3=0.1$, $a_1=a_3=1$, and $a_2=1$, 10, 100.

Fig. 1 Shows the results for two layer model. In Fig. 1 (1), profile of Rn existing in soil air (Bq.cm^{-3} of soil) is given as a parameter of $D_1=D_2=D$ assuming $a_1=1$, $a_2=100$, $H_1=100$

and $H_2=\infty$. In Fig. 1 (2), profile is given as a parameter of H_1 assuming $a_1=1$, $a_2=100$, $D_1=D_2=D=0.054/10$, and $H_2=\infty$.

Fig. 2 shows the results for three layer model. In Fig. 2(1), $C_s(z)$ (Bq.cm^{-3} of soil) is given as a parameter of $D_1=D_2=D_3=D$ assuming $a_1=a_3=1$, $a_2=100$, $H_1=H_2=100$, and $H_3=\infty$. Fig. 2 (2) gives the profile as a parameter of H_1 assuming $a_1=a_3=1$, $a_2=100$, $D_1=D_2=D_3=D=0.054/10$, $H_2=100$, and $H_3=\infty$.

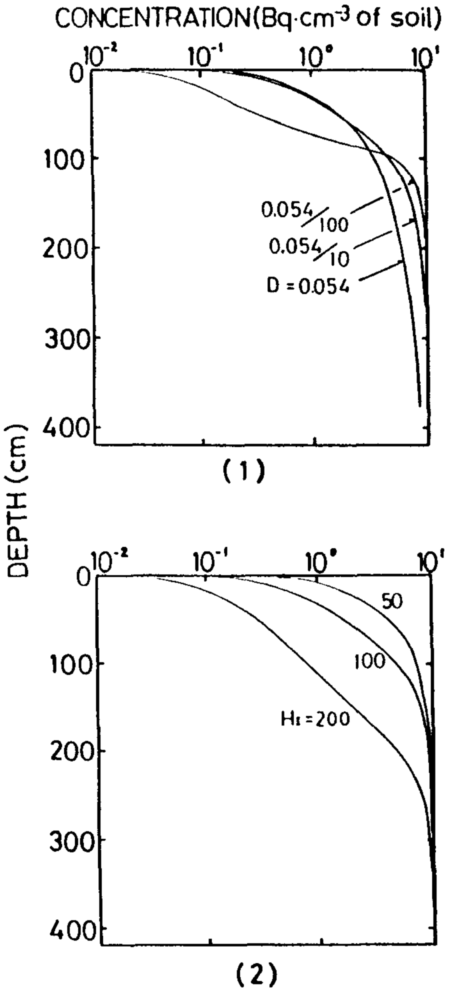


Fig. 1 Rn profile in soil (two layer model)

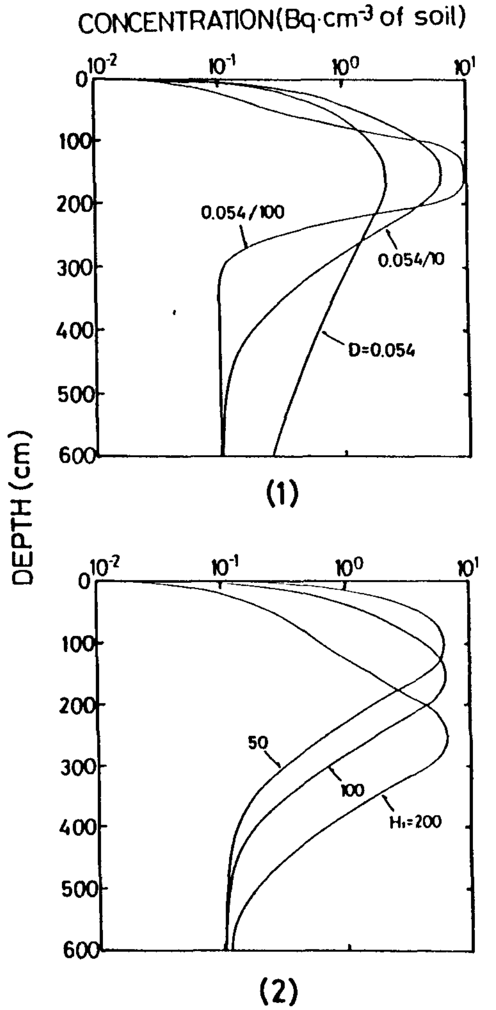


Fig. 2 Rn profile in soil (three layer model)

Fig. 3 shows the calculated exhalation rates, E, for two layer model (broken line) and for three layer model (solid line). In Fig. 3(1), E is shown as a function of H_1 for a parameter of $D_1=D_2=D_3=D$ assuming $a_1=a_3=1$, $a_2=100$, $H_2=\infty$ (two layer), $H_2=100$ and $H_3=\infty$ (three layer). Fig. 3(2) gives E as a function of H_1 for a parameter of a_2 assuming $a_1=a_3=1$, $D_1=D_2=D_3=D=0.054/10$, $H_2=100$, and $H_3=\infty$.

RESULTS AND DISCUSSIONS

Although the present model is simple and parameters used are assumptive, we may get some informations from the present calculation. Comparing Fig. 1 and Fig. 2, the profile of $D_S(z)$ for two layer model is quite different form that for three layer model. But as is shown in Fig. 3, exhalation rate for two layer model is not so much differ from that for three layer model. It is also seen that D is very effective for the value of E[3], which suggests that radon exhaled from wastes can be effectively reduced by covering of soil of low effective diffusion coefficient. The present treatment may also be applicable for natural multi-layer soil.

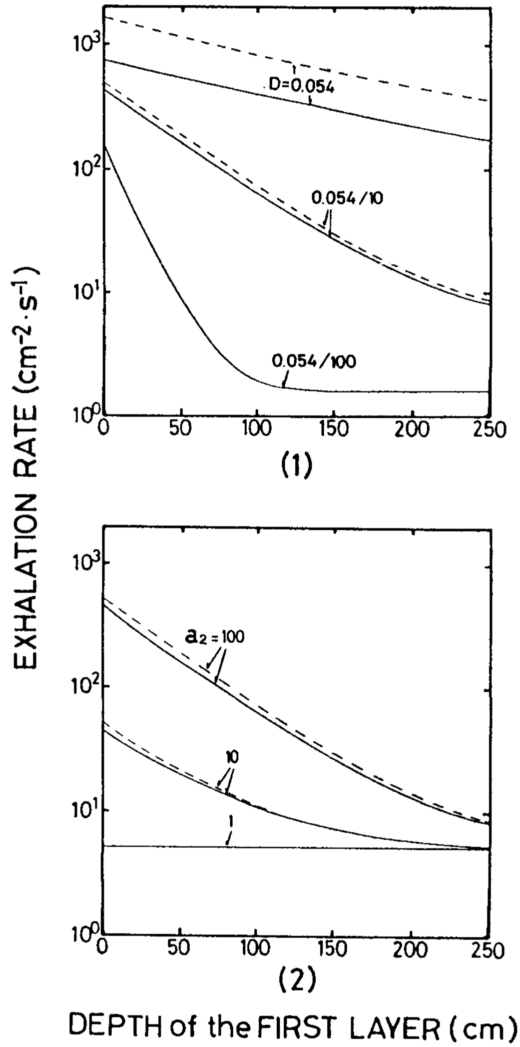


Fig. 3 Calculated exhalation rate as a function of the first layer

REFERENCES

1. Kataoka, T., Ikebe, Y., and Minato, S., 1979, Influence of the Distribution of Rn-222 Concentration under the Ground on Natural Gamma-Ray Flux Density and Exposure Rate, Health Phys., 37, pp.669-675.

2. UNSCEAR, 1982, Ionizing Radiation, Source and Biological Effects, Appendix D, pp.150-151, United Nations, New York.

3. Kataoka, T. and Ikebe, Y., 1982, Measurement of Soil Concentration Profile of Radon-222 and Its Effect on Exposure Rate, J. Nucl. Sci. Technol., 19, pp.757-761.