SHIELDING EFFECT OF SNOW COVER ON INDOOR EXPOSURE DUE TO TERRESTRIAL GAMMA RADIATION

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1. INTRODUCTION

Many people in the world live in high latitude region where it snows frequently in winter. When snow covers the ground, it considerably reduces the external exposure from the radiation sources in the ground. Therefore, the evaluation of snow effect on exposure due to terrestrial gamma radiation is necessary to obtain the population dose as well as the absorbed dose in air in snowy regions. Especially the shielding effect on indoor exposure is essentially important in the assessment of population dose since most individuals spend a large portion of their time indoors. The snow effect, however, has been rather neglected or assumed to be the same both indoors and outdoors in the population dose calculation. Snow has been recognized only as a cause of temporal variation of outdoor exposure rate due firstly to radon daughters deposition with snow fall and secondly to the shielding effect of snow cover. This paper describes an approach to the evaluation of shielding effect of snow cover on exposure and introduces population dose calculation as numerical example for the people who live in wooden houses in Japan.

2. ASSUMPTIONS

Representative conditions were assumed as follows. Snow covers the smoothed flat interface of infinite half space of ground, where an isolated house stands. Snow has a variety of density from 0.1 g/cm^3 of freshly fallen snow to more than 0.4 g/cm^3 of wet snow. Two typical values of 0.2 and 0.4 g/cm^3 were chosen for light and heavy snow, respectively. Soil moisture content is assumed to be constant regardless the depth of snow cover. The terrestrial radiation sources of uranium and thorium series, and potassium are assumed to be uniformly distributed in the ground. The radon daughters floating in the air are neglected as they contribute little to the total dose from natural background(1). In addition, the dose from the radon daughters deposited on the ground surface by precipitation in not taken into account since it is negligibly small as far as the annual dose is concerned. The house is assumed to be made of wood. Based on the indoor and outdoor exposure measurements in Japanese houses, the indoor exposure rates in wooden houses appear to be equal to outdoors(2). It is consequently assumed that wooden structures have little shielding effect on the radiation penetrating from the outside and no dose contribution from the building materials. The representative building area is assumed to be 60 m^2. The effect of the area size is also considered by changing the parameter. Occupancy factor of 0.8 and 0.2 for indoors and outdoors, respectively, is used to evaluate the population dose.

3. CALCULATIONS

Indoor gamma exposure sources can be divided into three components; (1) the building materials, (2) the soil under the house and (3) the soil outside the house. The first component is neglected in this paper, since it is assumed that building materials in wooden houses have no dose contribution to the indoor exposure rate. The other two are evaluated separately with a computer code based on the Adjoint Monte Carlo Method. The exposure resulting from the soil under the house can be estimated from the calculation of dose due to the radiation originating in a limited area. In this case it is not necessary to consider the shielding effect of snow even when snow covers the ground, since snow will not cover the area under the house. Whereas, the radiation emitted from the third source must penetrate the layer of snow to reach the house when the ground is covered by snow. The reduction of exposure by snow cover can be roughly estimated using the results[3] for the shielding effect of snow cover on the outdoor exposure. Further specification is necessary to obtain a better estimate of indoor exposure due to outdoor radiation. When there is a house, snow covers the ground only outside the house thus making a difference in the configuration of the snow cover. For this reason another series of shielding calculations was performed taking into account the presence of a house on the ground.

4. RESULTS AND DISCUSSION

Fig. 1 shows the dose contribution from radiation originating in the circular area of radius R m. It is shown as a fraction of the total exposure rate from the sources in the infinite area. The receptor is located 1 m above the center of the circle. The dotted line in the figure shows the solid angle at the receptor subtended by the area of radius R m. The exposure rate are lower than the subtended solid angle. The difference between the two lines reveals the fact that the dose contribution from a distance is larger than expected by the solid angle. Moreover, it shows the necessity of simulation calculation of exposure from the limited area to obtain dose from the source under the house. These results permit estimation of the dose contribution from the building area. When the building area is 60 m^2, the area provides 68% of the total exposure. This exposure fraction varies slowly with the size of the area. If this area decrease half or increase double, the fraction would change a little to 61 or 74%, respectively. It thus proves that the simplification in shape of the building area introduces no significant error. The residual of the fraction represents the dose contribution from the outside with no snow cover on the ground. The outdoor radiation contribution in the house is 32% for the building area of 60 m^2. This dose contribution is reduced further when snow covers the ground.

Fig. 2 shows the fractions of absorbed dose rates in air at 1 m above the ground surface as a function of snow cover. The solid line shows the shielding effect on outdoor exposure. Snow cover introduces an effective shielding of gamma radiation from ground sources. This calculation provides rough estimation of the exposure reduction due to snow cover. The simulation calculation considering the presence of a house shows that the exposure reduction inside the house is 10 to 30% larger than outdoors.

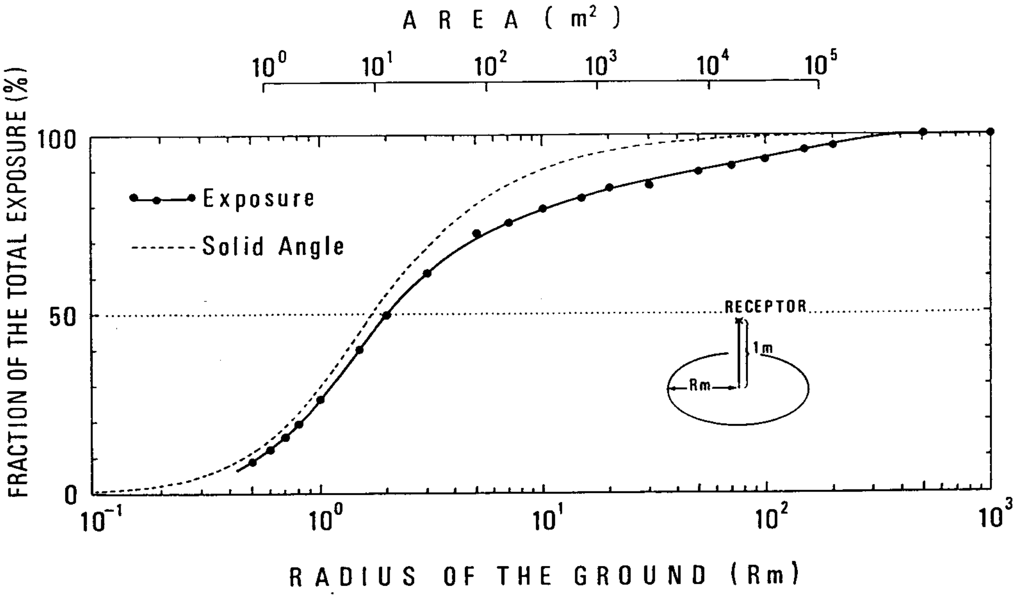

Fig. 1 Dose contribution from the circular area of radius R m to the receptor

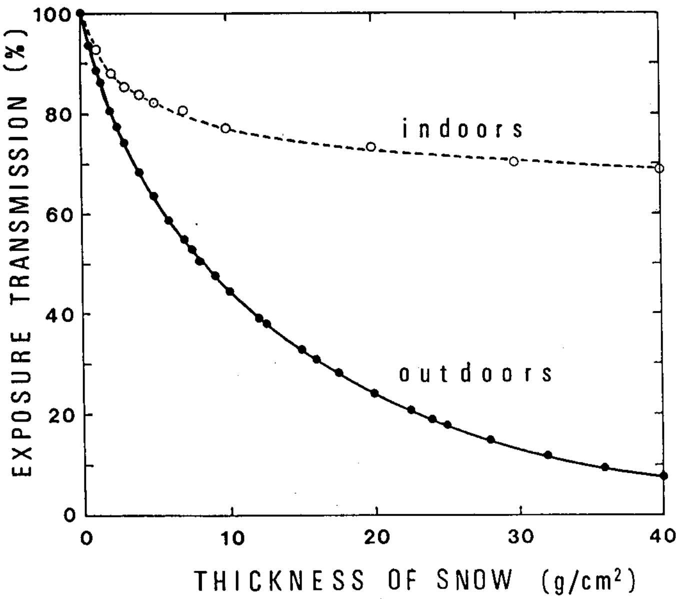

Fig. 2 Exposure transmission of terrestrial gamma ray
(**indoors:** Exposure transmission in the model house in this paper. **outdoors:** Exposure transmission in the open field)

The results for the representative house with a floor area of 60 m^2 is shown with the dotted line in Fig. 2 taking into account the outdoor dose contribution of 32% to the indoor exposure. Large shielding effect on outdoor exposure turns out to be small in the case of indoors due to the large contribution to the indoor exposure from the underlying soil. Fig.2 permits calculation of the reduction of exposure from the soil outside the house with snow cover on the ground surface. Verification of this calculation is not easy, since the ideal situation is hardly satisfied in actual condition. However, the present evaluation by computer simulation is in relatively good agreement with the results obtained by actual measurements.

5. POPULATION DOSE ESTIMATION

Population dose is estimated considering the snow effect on the indoor exposure in wooden houses. The amount of snow precipitation has varied substantially from place to place and year by year. The published values of average depth of snow cover over past 30 years in each city were used to evaluate the snow effect on population dose. The depth of snow cover is classified into a category of 5 groups; less than 10, 10 to 20, 20 to 50, 50 to 100 and more than 100 cm. The average number of days in each group has been reported. Since no data is available about snow density, two densities are chosen to estimate the range of the effect of snow cover. The annual outdoor absorbed dose in air was found to be reduced down to 43 or 57%, respectively for the density of 0.4 or 0.2 g/cm^3 in the northern part of Japan. Whereas, the corresponding values for indoor absorbed dose in air are 79 and 83%, respectively. When the occupancy factors are taken into account to obtain the annual dose, the corresponding values are 71 and 78%.

In the case of heavy structures, one has to take into account the walls as attenuators of outdoor radiation and also as sources of radiation. Hence the evaluation of snow shielding effect on the indoor exposure in concrete houses becomes rather difficult. The effect depends on the place in the house. At a position near the window, larger shielding effect might be found, since about half of the radiation comes from the outside. On the other hand, the center of the house has little snow effect due to both the predominant dose contribution and the large shielding effect by the wall.

6. SUMMARY AND CONCLUSION

The simulation calculation has shown that snow cover causes large reduction in the outdoor exposure due to terrestrial gamma radiation, but that the degree of the reduction decreases in indoors. When the shielding value in the outside is applied to estimate the population dose, it should cause a significant underestimation. However, one cannot neglect the snow shielding effect on population dose. Neglecting snow effect will cause more than 20% of overestimation for the people who live in wooden houses in snowy regions. Therefore, it is necessary to employ the approach described in the present paper to obtain a better estimate of population dose in wooden houses.

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