A STUDY OF THE BEHAVIOUR OF THE PRIMARY PARTICLES OF RADON DECAY PRODUCTS

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1. INTRODUCTION

The evaluation of risk due to breathing of air containing radon and its decay products has been always a challenging problem to a radiation protectionist. It is not known whether the inhalation risk based on the deposition of the primary particles (fraction unattached to aerosols) alone is sufficient. It has been shown that the unattached fraction varies considerably depending on the aerosol concentration (1). In this paper, the behaviour of the primary particles and their attachment to aerosols are studied and the risk due to deposition of the radon daughter aerosols in the lung is calculated.

2. BEHAVIOUR OF PRIMARY PARTICLES

A diffusion sampler described elsewhere (2) is used to measure the unattached fraction of the radon decay products. The studies are carried out in an aerosol free chamber, using highly filtered nitrogen as the medium of dispersion. Figure I gives the variation of the percentage of unattached fraction with time after filling radon in the chamber. In the figure, D is the delay given after replacing the air in the chamber by aerosol-free nitrogen. D has an effect in reducing the aerosol-forming species in nitrogen. Very small aerosols formed due to natural background ionisation are lost to the walls of the chamber due to rapid diffusion.

Depending on D and the concentration of radon introduced, aerosols are formed in the chamber, which affect the behaviour of the primary particles. The size of the aerosols formed changes with time so that the region of deposition of these particles in the lung is different. It is thus very difficult to define the primary particles and assess the risk on the basis of the unattached fraction alone.

3. ATTACHMENT OF PRIMARY PARTICLES TO AEROSOLS

The attachment of the primary particles to the aerosols formed is studied by measuring their concentrations. The degree of attachment (S_t) is proportional to the concentration of aerosols (N_t). Thus we can write

$$P = S_t/N_t,$$

where P is the attachment parameter. P is directly proportional to the diffusion coefficient of the primary particles and inversly to that of the aerosols. Table 1 gives the variation of P with time for D = 1 and 6 days.

An increase in the size of the aerosols formed by nucleation (vapour phase) and coagulation is likely to result in an increase in P. P decreases when

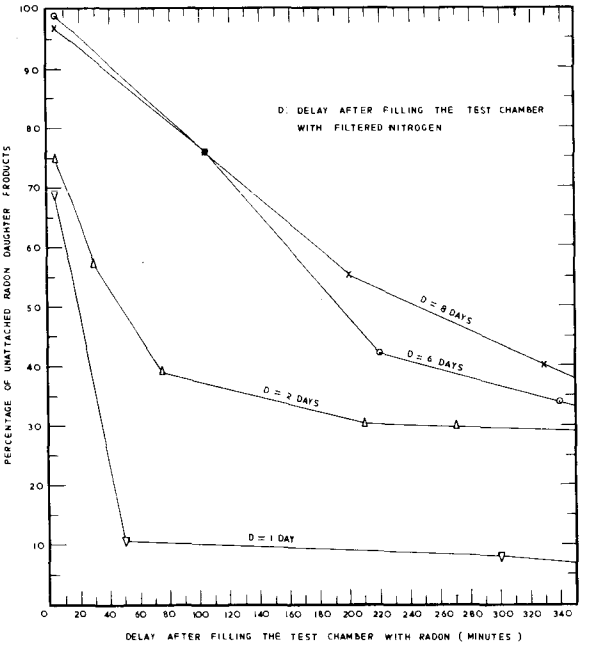

FIGURE I VARIATION OF PERCENTAGE OF UNATTACHED RADON DAUGHTER PRODUCTS WITH TIME AFTER FILLING RADON IN THE CHAMBER.

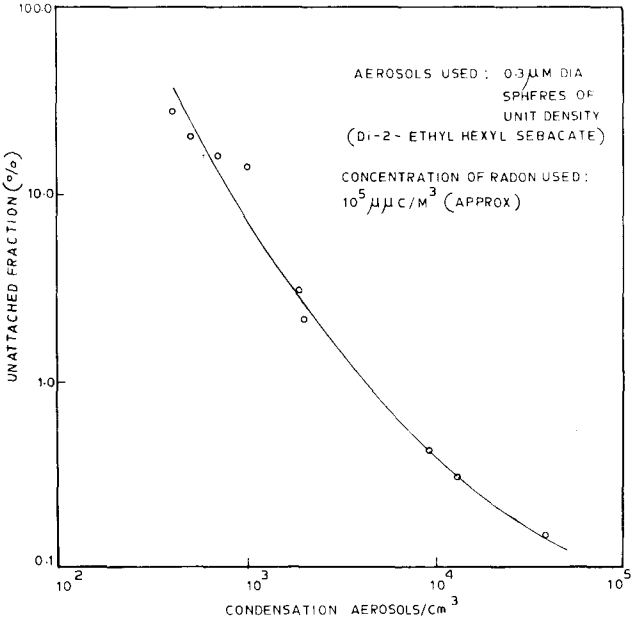

FIGURE II. A STUDY OF THE VARIATION OF THE UNCOMBINED FRACTION OF RADON DAUGHTERS WITH AEROSOL CONCENTRATION IN THE TEST CHAMBER.

the diffusion coefficient of the primary particles decreases. This indicates that they grow in size due to nucleation. P for D = 6 days is less than for D = 1 day, showing that the size of the particles formed in

D = 1 day		D = 6 days	
Time (min)	P (cm^3)	Time (min)	P (cm^3)
20	7.1×10^{-4}	20	1.4×10^{-4}
50	9.2×10^{-4}	50	1.7×10^{-4}
100	6.9×10^{-4}	100	2.6×10^{-4}
150	6.1×10^{-4}	150	3.6×10^{-4}
200	5.4×10^{-4}	200	4.5×10^{-4}
250	5.6×10^{-4}	250	4.9×10^{-4}
300	6.1×10^{-4}	300	5.5×10^{-4}

TABLE 1 Variation of the Attachment Parameter P with time after filling the chamber with radon.

the former case is very much less than in the other.

Experiments using different concentrations of 0.3 and 0.5 μm dia. aerosols (unit density spheres) have shown that the unattached fraction can be reduced to as low as 0.5% (Figure II). Then, on the basis of the present criterion (ICRP), the effective dose to the lungs reduces by a factor of 16. This is obviously controversial since it is not possible to reduce the inhalation risk in an uranium mine by introducing appropriate concentrations of aerosols. Depending on the chemical nature and solubility of the aerosols, the dose to the lung would increase significantly, particularly for α-emitters.

4. CALCULATION OF THE INHALATION DOSE

Calculation of the dose to the lung due to the presence of 3×10^4 μμc/m^3 of radon in air, in equilibrium with its decay products, has been made using the weibel's anatomical model (3). The fractions of decay products attached to aerosols of different sizes as found in a typical industrial atmosphere are calculated using appropriate attachment coefficients. The clearance of the deposited activity depending on the velocity of the mucous is taken into account. The activity deposited in the region beyond the segmental bronchi is assumed to decay completely in the lung. With such a deposition model, the radiation dose works out to be 10 times the

MPD of 15 rems per year.

5. COMMENTS

The studies reported here show that the inhalation of alpha emitting isotopes is highly hazardous. The dose due to the deposition of the insoluble aerosols carrying alpha emitters in the lung is significantly high for long residence times of the deposited particles.

The risk of carcinogenesis by alpha radiation does not depend on the linear risk hypothesis and is actually under-estimated for high LET radiation. Chromosomal structural changes due to alpha interactions is highly localised so that the relative biological effectiveness increases markedly. This poses an important question whether the MPD of 15 rems per year for inhalation risk evaluation is rather high.

The analysis carried out in the present study is also important for risk estimation due to the presence of natural alpha emitters in air and cigarette smoking (4).

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