A METHOD FOR DETERMINING DOSES IN THE INHALATION OF RADON DECAY PRODUCTS

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Original article submitted January 12, 1960

This article gives a new method for determining the absorbed energy in the inhalation of radon decay products from the number of α-particles emitted during the total decay of daughter products of radon separated from 1 liter of air. A method is proposed for determining the concentration of radon from the number of α-particles emitted due to total decay of the daughter products collected on a filter from a continuously purified volume.

The determination of doses in the inhalation of radioactive material is a very complex problem. In fact, its solution requires information not only on the quantity of each separate radioactive substance introduced into the organism but also its distribution within the organism. The latter depends on many widely fluctuating factors and it can therefore hardly be studied in a general form.

In addition, it is obvious that since the amount of material taken by the organism during inhalation depends on the quantity of these materials in the air, the study of the whole complex of problems should rest on accurate data as to the content of radioactive substances in the air.

Calculation shows that during the inhalation of radon decay products the dose is mainly determined by the α-radiation, since the energy and biological activity of the β-radiation compared with the α-radiation is negligibly small. The main attention is therefore paid to the study of α-active products [1].

The methods now used for the determination of radon decay product concentrations in the air are based on the determination of RaA, RaB and RaC. The latter is achieved either by analyzing curves for the decay of radioactive substances collected on a filter from a given volume of air [2] or by analyzing the amplitudes of impulses given by the α-particles leaving the surface of the filter [3]. These methods are complex, which prevents their widespread use. Furthermore, with low contents of radioactive substances in the air, close to the natural background, the analyses of the decay curves and the impulse amplitudes are hindered due to the high statistical scatter of the experimental points. The method considered in this article is largely free from these faults.

We will determine the energy formed during the total decay of α-active atoms separated from 1 liter of air:

$$E_1 = a (E_{RaA} + E_{RaC'}) + (b + c) E_{RaC'},$$

(1)

where $E_1$ is the total energy; $a$, $b$, $c$ are the number of atoms of RaA, RaB, RaC (in 1 liter of air) respectively; $E_{RaA}$ and $E_{RaC}$ are the energies liberated during one act of decay of the appropriate element.

Formula (1) can be written in a different way if we average the energy of α-radiation of RaA and RaC'. We will represent this value by $E_{a\alpha}$. Then

$$E_2 = E_{a\alpha} (2a + b + c) = E_{a\alpha} n,$$

(2)

where $n$ is the number of α-particles emitted during total decay of radon products separated from 1 liter of air.

Calculation shows that if we assume $E_{a\alpha} = 7.35$ Mev, then the deviation of $E_1$ from $E_2$ with a change in the ratio $a\lambda_1 : b\lambda_2 : c\lambda_3$ ($\lambda_1$, $\lambda_2$, and $\lambda_3$ are the decay constants of RaA, RaB and RaC, respectively) from 1 : 1 : 1 to 1 : 0, 1 : 0.01 varies within the limits ± 3.5% from $E_1$. In view of the fact that in the important practical cases the deviation from the equilibrium concentrations varies by not more than the limits shown above, the replacement of $E_2$ by $E_1$ can be considered valid.
We will assume, as is usual, that in the inhalation of decay products there is no selective absorption of radioactive materials, i.e., the coefficient of capture \( \eta \) is the same for each of the radon decay products. Then the total energy of radioactive decay liberated within the organism on the inhalation of 1 liter of air is

\[
E = \eta n E_a.
\]

(3)

These discussions show that the initial value for the termination of doses in the inhalation of daughter products of radon can be \( n \), i.e., the number of \( \alpha \)-particles emitted during complete decay of radon daughter products, separated from 1 liter of air.

We will deal with different methods for determining the value \( n \).

1. A fixed amount of air is drawn through a filter with a known filtration efficiency \( \phi_B \). The \( \alpha \)-particles leaving the surface of the filter are recorded by an apparatus. Depending on the geometry of the count and the self-absorption in the filter, the efficiency of recording \( \phi_a \) can be different. Then, establishing a continuous count of particles from the start of filtration and up to complete decay of the radioactive materials collected on the filter, it is possible to determine \( n \):

\[
n = \frac{N_p}{vt \phi_a},
\]

where \( N_p \) is the total number of \( \alpha \)-particles recorded by the apparatus; \( v \) is the rate of evacuation (liter/min); \( t \) is the time during which filtration takes place (min).

2. The second method is based on the assumption that if, with a fixed rate of evacuation \( v \), the number of \( \alpha \)-particles \( n_p \) recorded in unit time does not change over a large interval of time, then during time \( \Delta t \) within this interval, the number of radioactive atoms remains constant. In other words, during the time \( \Delta t \) the number of radioactive atoms settling on the filter is the same as those which decay during this time.

We will assume that during time \( \Delta t \) one liter of air passes through the filter and that it collects \( \phi_B (a+b+c) \) atoms of RaA, RaB, RaC. According to the condition, the same number of atoms should decompose during this time. The corresponding total number of decays \( \phi_a(2a+b+c) = \phi_a n \). Hence, it can be seen that if the count rate is equal to \( n_p \) impulses per minute and the rate of evacuation \( v \) liters per minute, then the total number of decays is

\[
n = \frac{n_p}{v \phi_a}.
\]

To use the above method for determining doses, in collaboration with A. M. Konstantinov, we developed an apparatus which could continually record \( \alpha \)-particles leaving the filter. One form of the apparatus is a somewhat modified scintillation attachment to the B type apparatus.

A fixed volume of air recorded by a gas counter was drawn through the filter, the \( \alpha \)-particles being recorded directly from the moment of start of filtration. The rate of evacuation was measured with a rheometer. The number of impulses was counted every minute. The total number of impulses was recorded simultaneously.

In the first series of experiments, the filtration was carried out during time \( t \) and the number of decays from the start of filtration and up to complete decay of the radioactive material was recorded directly by a mechanical counter. In the second series of experiments, air was drawn for a long time through the filter with a constant rate so that the count rate \( n_p \) was constant.

The first case corresponds to a short stay of the organism in the contaminated atmosphere, the second corresponds to a long period when a more or less constant concentration of radioactive materials is established in the organism, different from their concentration in the inhaled air.

The amount of suspensions in the atmospheric air varies with time; the measurements were therefore made with two identical instruments, operating simultaneously. The air samples were taken from the same volume.

It was established that the number of \( \alpha \)-particles emitted during the total decay of daughter products of radon, separated from 1 liter of air is almost independent of the method of determining the radon daughter products. Thus, despite the fact that the relationship RaA:RaB:RaC on the filter depends on the rate and time of filtration, the total number of decays (on the same filter) is the same in all cases, if the same amount of air is drawn simultaneously through both filters.