The Closed-Can Exhalation Method for Measuring Radon

1. Background

The closed-can method is a well-known and established way of measuring radon outgassing from porous samples. Unfortunately, the interpretation of experimental results has frequently been based on assumptions that are in conflict with the basic laws of diffusion. The erroneous and, one could say, classical approach is to fit the radon build-up in the accumulator to the equation

\[ A = E \left( 1 - e^{-\lambda t} \right) \]  

where

- \( A \) = radon activity in enclosure (Bq),
- \( \lambda \) = decay constant of radon-222 (s\(^{-1}\)),
- \( E \) = exhalation rate (Bq s\(^{-1}\)),
- \( t \) = duration of enclosure (s).

It is assumed without evidence that the exhalation rate \( E \) is initially constant, typically for several hours after closing the accumulator. Diffusion theory calculations show that this is not true for samples which are thin compared with the diffusion length. Including effects of leakage and the so-called “back diffusion” in eq (1) by incorporating an “effective” decay constant \( \lambda^* \) instead of \( \lambda \) is even more suspect. Equation (1) is typical for first-order kinetics and cannot successfully be imposed on pure diffusive transportation processes.

2. Results and Discussion

A 20-cm thick sample in an accumulator of height 30 cm will typically exhibit the exhalation rate illustrated in figure 1 if the thickness, \( d \), is less than the diffusion length, \( L \). The corresponding cumulative concentration curve [fig. 1(b)] will, in an experimental situation, falsely give the impression of being linear.

In order to reveal the rapid initial change in exhalation rate experimentally one has to follow the radon concentration build-up in the enclosed air volume more or less continuously. In figure 2 theoretical and experimental radon values for a 26-cm
Figure 1. The temporal evolution of a) radon exhalation rate and b) the corresponding radon growth in the outer volume after closing a radon-tight accumulator. Diffusion length=2 m. (Theory).

Figure 2. Radon concentration growth from enclosed dry sand mixed with 11% ground uranium ore by weight. Radon diffusion length=1.4 m, emanation fraction=0.33, radium-226 concentration =1.2 kBq kg\(^{-1}\), and bulk density=1710 kg m\(^{-3}\).

In general it is not relevant to fit simple exponential formulas to results from closed-can exhalation measurements.

Certain sample/accumulator geometries are definitely unsuitable for free exhalation determination unless the radon growth is monitored more or less continuously and the results are interpreted by means of a time-dependent diffusion theory.

The mean exhalation rate during the first hours is approximately equal to the free and undisturbed exhalation only if the outer volume of air is much larger than the pore volume or the sample thickness is much larger than the radon diffusion length.
4. Acknowledgment

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5. Reference

[1] Samuelsson, C., and Erlandsson, K., in Radiation Protection Practice Vol. II, Pergamon Press, Sydney (1988) p. 898.