Pergamon

Nucl. Tracks Radiat. Meas., Vol. 22, Nos 1–4, pp. 455–458, 1993
Elsevier Science Ltd
Printed in Great Britain.
0969-8078/94 $6.00+.00

RADON DIFFUSION STUDIES IN AIR, GRAVEL, SAND, SOIL AND WATER

BALJINDER SINGH, SURINDER SINGH and H. S. VIRK

Department of Physics, Guru Nanak Dev University, Amritsar 143005, India

ABSTRACT

Radon isotopes are practically inert and have properties of gases under conditions of geological interest. During their brief lives, their atoms are capable of moving from the sites of their generation. Radon diffusion studies were carried out in air, gravel, sand, soil and water using silicon diffused junction electronic detector, Alphameter-400. Diffusion constant and diffusion length is calculated for all these materials.

KEYWORDS

Radon; porosity; diffusion; cylinder.

INTRODUCTION

Radon is a radio-active but chemically inert gas and is, capable to diffuse through microscopic imperfection such as crevices, pores and structure failures (Culot et al., 1976; Cothern and Smith, 1987; Poffijin et al., 1988; Jarzemba et al., 1989). It is produced in the soil due to the presence of ^{238}U and is transported to atmosphere by turbulent diffusion. The concentration of radon in the atmosphere has been shown to be useful as an indicator of atmospheric mixing processes. Radon diffusion and transport through different media is a complex process and is affected by several factors (Tanner, 1980, Ghosh and Seikh 1976).

The present study has been carried out in the laboratory on the behaviour of radon diffusion through air, gravel, sand, soil and air. Diffusion constant and diffusion length is calculated for all these materials.

EXPERIMENTAL TECHNIQUE

In the present studies a silicon diffused junction electronic detector alphameter-400, which can record integrated radon concentrations over short time periods has been used. Alphameter-400 is calibrated already in this laboratory using 200 k Bq radium chloride standard solution (Singh et al., 1986). For radon source uranium rich ore in powder form in the cavity was used. Since more than 80 % radon is able to pass through fine latex rubber membrane (Giridhar et al., 1982; Ramachandran et al., 1987), so latex memberane is used membrene (65 um thickness) to protect the source from diffusing materials. An aluminium cylinder (4.5 cm in diameter) with a screw cap at one end was deployed vertically. The radon source is fixed at the bottom of the cylinder in the cavity of screw cap. It was filled with material of known density and porosity and the Alphameter-400 was fixed at the top (Fig.1).

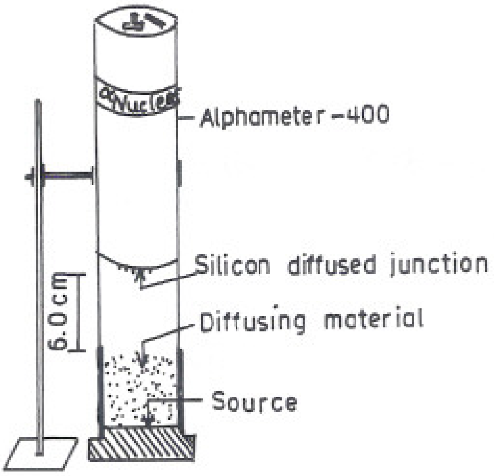

Fig.1. System of radon diffusion through soil.

The system was sealed finely by using vaccuum grease and the count rates were recorded after a fixed interval of time untill the saturation was attained. The experiment was repeated for varying diffusing medium viz. Air, Gravel, Sand Soil and water and different heights of the cylinder i.e. 5.0, 26.8, 46.8, 67.1 and 85.1 cms. The statistical error of nuclear counting was reduced to less than 1 % by increasing the measurement time period and the error due to background is eliminated by repeating the experiment without source.

RESULTS AND DISCUSSION

The radon build up at the source with time is given in Fig.2. The saturation value of radon is measured which gives the concentration of radon at the source. By using this source, build up of radon through different medium at various thickness of filling materials was measured. In Figs. 3-7, the results of radon diffusion measurements are shown as a function of thickness for different materials. In these experiments, the density of solids was kept constant. The porosity of gravels, sand and soil was 53.46 %, 50.42 %, 28.15 %, respectively.

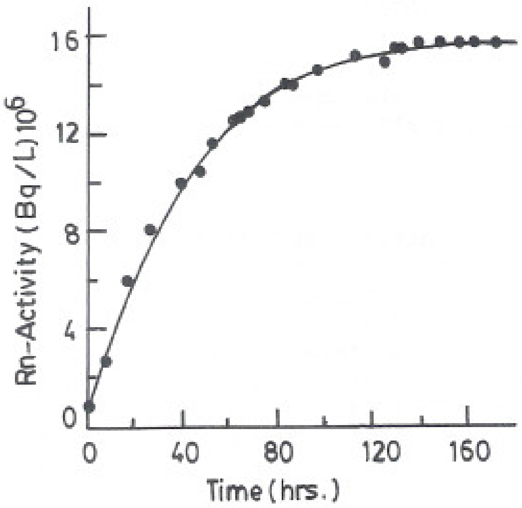

Fig. 2. Growth of radon activity with time at source.

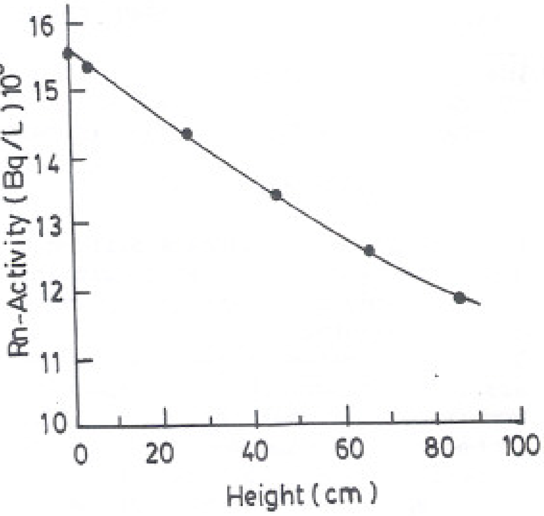

Fig. 3. The variation of radon activity with air coulmn.

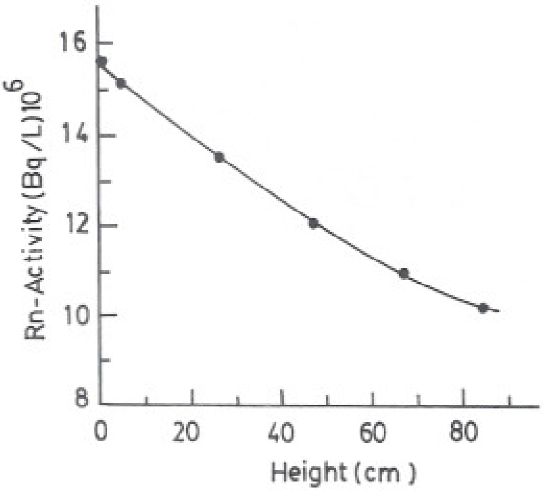

Fig.4. The variation of radon activity with gravel thickness.

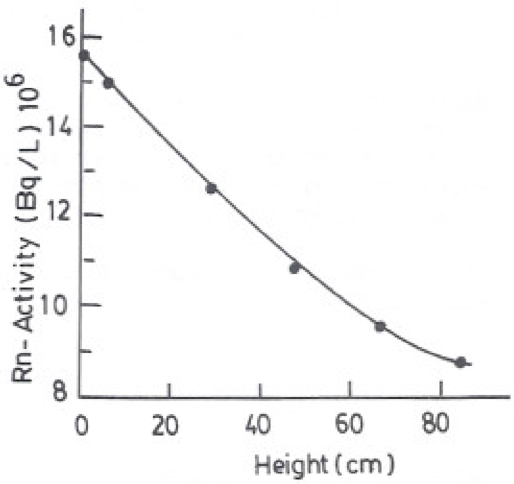

Fig.5. The variation of radon activity with sand thickness.

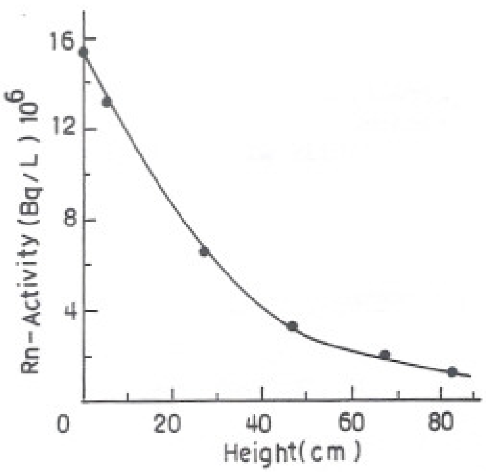

Fig. 6. The variation of radon activity with soil thickness.

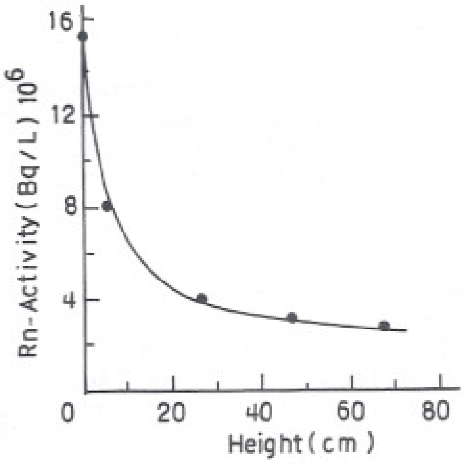

Fig. 7. The variation of radon activity with water coulmn.

The experimental results reveal that the radon diffusion is independent of density of the material and depends strongly on porosity. The values of diffusion coefficient and diffusion length calculated from these experiments is given in Table 1.

Table 1: Diffusion constant and diffusion length of radon in different media.

Medium	Density gm/cm^3	Porosity (%)	Diffusion constant (cm^2/sec.)	Diffusion length (cm)
Air	0.11	100	2.11×10^{-1}	316.23
Gravel	2.27	53.46	7.59×10^{-2}	190.15
Sand	2.27	50.42	4.41×10^{-2}	145.09
Soil	2.27	28.15	2.29×10^{-3}	33.04
Water	1.00	≈ 0	1.97×10^{-4}	9.68

It is evident that radon diffusion coefficient is found to be higher in case of air as compared to that in gravels, sand, soil and water. This may be due to higher porosity value of air as compared to other media. Since water has negligible porosity, so, radon should not pass through the water column. The crossing of radon through water may be explained as: Radon is an inert and water soluble gas. It is dissolved in water and since the water molecules are continuously in motion, the radon atoms can travel through these molecules and pass through the water coulmn.

The observed behaviour of radon diffusion through materials obeys the equation

$$N = N_o \exp [(-\lambda/D)^{1/2} x]$$

where N, is the concentration of radon at any time, t at a distance, x cm away from source. λ, is the decay constant of radon, D, is the diffusion coefficient of radon and N_o is the radon concentration at the source.

CONCLUSIONS

The following conclusions are drawn:

1) The rate of diffusion depends upon porosity of the medium and is nearly independent of the density of medium.
2) The radon concentration decreases exponentially with the increase in thickness of the medium.

REFERENCES

Cothern, C.R. and J.E. Smith. (1987). Environmental Radon. Plenum Press, New York.

Culot, H.V., Olson, H.G. and K. Sciager. (1976). Effective diffusion coefficient of radon in concrete theory and methods for field measurements. Health Phys., 30, 263-270.

Ghosh P.C. and I.A. Sheikh (1976). Diffusion of radon through inactive rock section. Ind. J. Pure and Appl. Phys., 14, 666-669.

Giridhar J., M. Raghavayya and N. Padmanabham (1982). Radon permeability of some membranes. Health Phys., 42, 723-725.

Jarzemba T.E., J. Blue, J. Mervis., D. Halcomb (1989). Diffusion of radon gas into soil cavities. Trans. Am. Nucl. Soc., 60, 87-88.

Poffijin, A., P. Berkvens., H. Vanmarcke., R. Bourgoignie (1988). On the exhalation and diffusion characteristics of concrete. Radiat. Prot. Dosimet., 24, 203-206.

Ramachandran T.V., B.Y. Lalit. and U.C. Mishra (1987). Measurement of radon through some membranes. Nucl. Tracks Radiat. Meas., 13, 81-84.

Singh, M., N.P. Singh., S. Singh and H.S. Virk (1986). Calibration of radon detectors. Int. J. Radiat. Appl. Instrum., 12, 739-742.

Tanner, A.B. (1964). Radon migration in the ground: A review. The Natural Radiation Environment. University of Chicago Press, 161-190.

Tanner, A.B.(1980). Radon migration in ground: A supplementary review. The Natural Radiation Environment III. (T.F. Gedsell and W.M. Lowder. Eds.), University of Chicago Press, pp. 5-56.