Nucl. Geophys. Vol. 4, No. 4, pp. 479–482, 1990
Int. J. Radiat. Appl. Instrum. Part E
Printed in Great Britain.

0886-0130/90 \$3.00 + 0.00

163 161

Influence of Moisture Content on Radon Diffusion in Soil

M. SINGH, R. C. RAMOLA, S. SINGH and H. S. VIRK

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

(*Received* 1 *March* 1990; *received for publication* 18 *July* 1990)

Abstract—Radon diffusion from soil has been studied as a function of the moisture content of the soil. A few simple experiments showed that up to a certain moisture content the radon diffusion increased with increasing moisture. A sharp rise in radon concentration occurred as the moisture was increased from the completely dry state to 13% water by weight. The radon flux was measured for columns of dry, moist and water saturated soil. The highest flux came from the column filled with moist soil. Water saturated soil gave the lowest flux because of the much lower diffusion coefficient of radon through water.

1. INTRODUCTION

Radon is released from building materials, rocks and soil into the environment (Tanner, 1978). This involves two mechanisms: liberation from the individual grain in which it is formed and transport through bulk medium to a free surface. The fraction of radon atoms that escape from a mineral grain is termed the emanation coefficient. The transport rate is usually characterized by the diffusion coefficient in the bulk medium. Radon diffusion and transport mechanisms through these materials are complex and affected by several factors (King, 1978; Shapiro *et al*., 1980; Strong and Levins, 1982; Stranden *et al*., 1984; Singh *et al*., 1988), one of the most influential being the moisture content of the exhaling material.

Quantification of the influence of moisture on radon diffusion from soil is of interest in radiation protection. Furthermore, it should contribute to an understanding of some of the micro-processes involved in radon transport through the ground. In this paper, the results of a study of the influence of moisture content on radon transport are reported.

2. EXPERIMENTAL PROCEDURE

Homogeneous soil was kept under water for 24 h. Surplus water was then removed and the weight of the soil recorded. The soil was then enclosed in a cylinder 30 cm by 4.5 cm dia, with a screw cap at one end. With the cylinder in a vertical position, about 100 g of pitchblende was placed at the bottom of the cylinder, in the cavity of the screw cap. At the other end of the cylinder, an Alphameter-400 was attached (Fig. 1). The build-up of radon in the container was measured after a given time.

After this initial experiment, the soil was gently heated at 100°C to reduce the moisture content. The soil was then allowed to cool to room temperature before it was weighed and enclosed in the container for renewed growth. In this manner, the moisture content of the soil was decreased stepwise and radon exhalation measurements were performed for each step. Finally, the soil was heated at 150°C for 24 h to render it dry.

3. RESULTS

Laboratory observations

The radon diffusion rate was determined by measuring the radon build-up with time at varying soil moisture contents (Fig. 2). Figure 3 shows the general trend for radon diffusion rate vs moisture

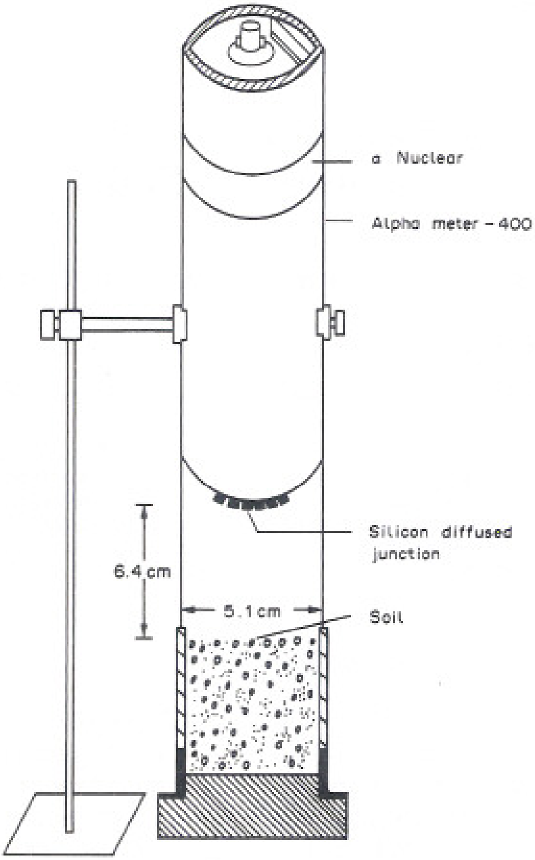

Fig. 1. Apparatus for study of radon diffusion through soil.

content. The experimental results indicate that, as the percentage content is increased from the dry state to 13% water, there is a sharp rise in the radon diffusion rate. The radon activity increases from 1.4×10^6 to 10.5×10^6 Bq/L. Thereafter it reduces to 0.1×10^6 Bq/L when the soil becomes water saturated (23% water). On average, the radon diffusion rate for moist soil is almost seven times greater than that of dry soil.

Field observation

Radon has been continuously monitored in soil since January 1984. The measured radon concentrations during the period of rainfall are shown in Fig. 4. The radon activity falls drastically after heavy rain (Events A, Fig. 4) and then starts to increase considerably over a period of several days. During light rain or drizzle, the radon values show an increasing trend (Events B, Fig. 4). The correlation coefficient (-0.42), computed for the daily radon observations in the field, also shows an inverse relation with rainfall.

4. DISCUSSION

The mechanism by which moisture affects the radon diffusion is understood only in qualitative terms. Radon decays from its parent ^{226}Ra with some recoil energy and thus is able to migrate to a free surface. However, the recoil range of radon is about 60 μm in air and only about 0.04 μm in minerals (Tanner, 1964). In dry soil, most of the radon atoms escaping from a mineral grain bury themselves in other grains. If the pores contain water rather than air, the recoiling radon atoms encounter a dense (energy) absorber. Radon absorbed in a water film can interchange with the air and diffuse through the air space in the pore. As a result active transport of radon takes place and results in the high radon concentration for moist soils. On the other hand, radon diffusion is much slower when the pores are completely filled with water. The diffusion coefficient for water

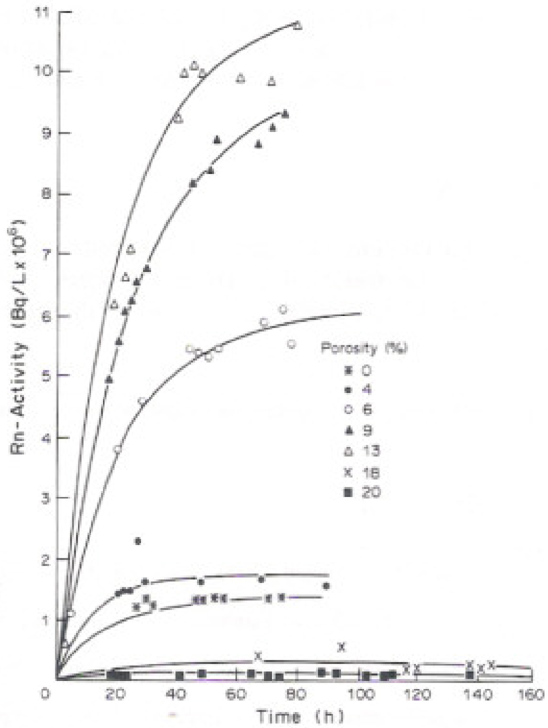

Fig. 2. Growth of radon activity with time at varying moisture contents.

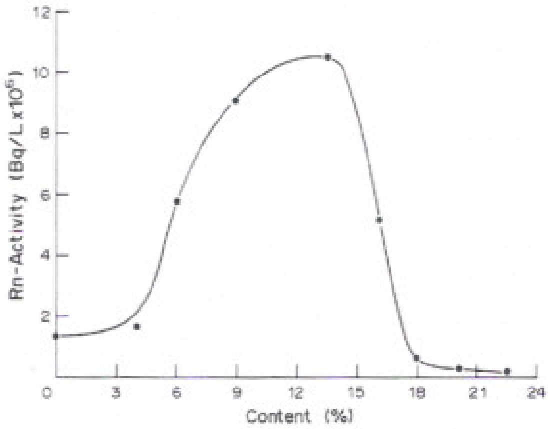

Fig. 3. Variation of radon activity with moisture content.

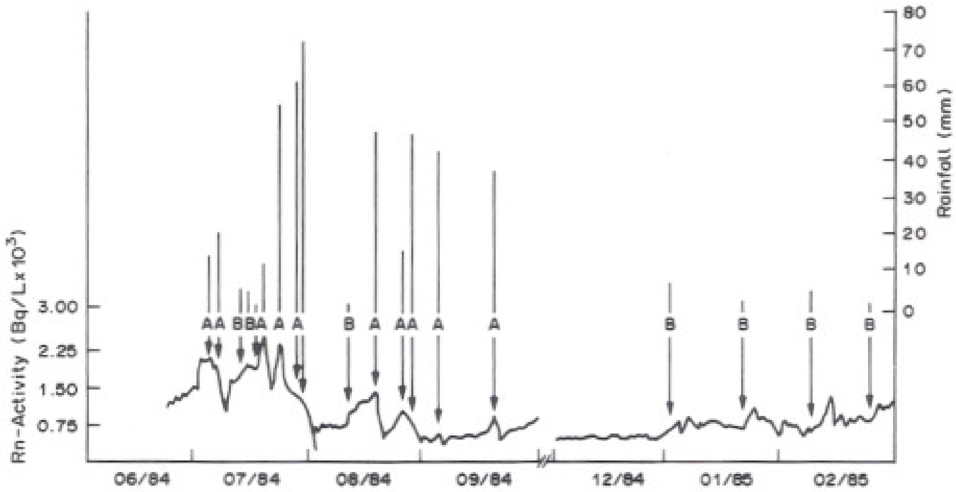

Fig. 4. Variation of soil–gas radon activity during a period of rainfall.

is about $10^{-5}\ cm^2\ s^{-1}$ compared to air ($10^{-2}\ cm^2\ s^{-1}$). When internal pores become saturated, free water appears in the interstitial spaces between particles and the diffusion coefficient is markedly reduced. The reduction in flux varies according to the percentage saturation of the interstitial void space. The decrease in soil gas radon in field observations is due to the fact that the pores in the soil are completely filled with water and the diffusion coefficient for radon in the water-saturated soil is greatly reduced. Thereafter, as the moisture content in soil decreases, active transport of radon on water molecules takes place. Finally, it comes to the normal level when the soil is nearly dry. During light rain, or drizzle, the radon values increase due to the closure of capillary pores on the upper surface of soil by the light rain shower. The emanation from the top layer of the soil is stopped resulting in an accumulation of radon below the impervious layer and is available in excess at the bottom of auger hole. The results obtained in the field for soil gas radon variation during the rainfall show correspondence to those obtained in the laboratory with varying moisture contents in soil.

5. CONCLUSION

The diffusion coefficient of radon increases with moisture content and appears most predominant at ~13% water. The lowest diffusion rates are observed for water-saturated soil. Variations of radon concentration in the field show a near-perfect match with the results obtained in laboratory experiments for similar moisture contents in soil.

Acknowledgements—The authors acknowledge financial assistance by the Council of Scientific and Industrial Research and the Department of Science and Technology, New Delhi.

REFERENCES

King C. Y. (1978) Radon emanation on San Andreas fault. *Nature* **271,** 515–519.

Shapiro M. H., Melvin J. D. and Tombrello T. A. (1980) Automated radon monitoring at a hard rock site in the southern California transverse ranges. *J. Geophys. Res.* **85,** 3058–3064.

Singh M., Ramola R. C., Singh S. and Virk H. S. (1988) Influence of meteorological parameters on soil gas radon. *J. Assoc. Explor. Geophys.* **IX,** 85–90.

Stranden E., Kolstad A. K. and Lind B. (1984) Radon exhalation: Moisture and temperature dependence. *Health Phys.* **47,** 480–484.

Strong K. P. and Levins D. M. (1982) Effect of moisture content on radon emanation from uranium ore and tailings. *Health Phys.* **42,** 27–32.

Tanner A. B. (1964) Radon migration in ground: a review. *Natural Radiation Environment* (Eds Adams J. A. S. and Lowder W. M.), pp. 161–190. Univ. of Chicago Press.

Tanner A. B. (1978) Radon migration in ground: A supplementary review. U.S. Geological Survey, Open File Report 78-1050.