1° 70

Nuclear Tracks, Vol. 12, Nos 1-6, pp. 739-742, 1986.
Int. J. Radiat. Appl. Instrum., Part D
Printed in Great Britain.

0191-278X/86 $3.00+.00
Pergamon Journals Ltd.

CALIBRATION OF RADON DETECTORS

Manwinder Singh, N.P. Singh, Surinder Singh and H.S. Virk

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

ABSTRACT

The detectors used for the radon estimation are calibrated in order to express the radon concentration from tracks/mm^2 hr and counts/min in terms of absolute activity in pCi/ml. The distribution characteristics of radon gas in a liquid-gaseous interphase are made use of in the calibration.

KEY WORDS

Radon; alpha-activity measurements; radioactive equilibrium; LR-115 and CR-39 plastic detector.

INTRODUCTION

Radon isotopes are produced in the three naturally occuring radioactive decay series. Being inert gases, these isotopes have the ability to migrate from their sources. However, their r respective half lives greatly limit the distance these can travel. Rn (222) is the only isotope which can migrate a significant distance from its source due to its sufficient long half life (3.825 days). The detection and estimation of Rn (222) content in the subsoil atmosphere is useful for uranium exploration.

The techniques employed for the Rn (222) estimation can be classified into two categories: (1) instantaneous techniques (Tewari et al., 1968; Dyck, 1969; Pacer and Czarnecki, 1980) which measure the radon content in soil gas collected over several minutes, and (ii) the time-integrated techniques (Gingrich and Fisher, 1976; Fleischer and Likes, 1979; Warren, 1977; Singh et al., 1984), which measure radon response accumulated over 3 to 30 days. Under the first category, the emanations are sampled out from auger holes and are monitored for alpha activity of radon and its short-lived daughter nuclides in terms of counts per minute. Under time-integrated techniques, the alpha-sensitive plastic track detectors are exposed to the auger hole environs recording alpha track density as a measure of radon concentration. The present work reports the calibration of the radon detectors used in instantaneous (Radon measuring System Type RMS-10) and time integrated (Alphameter-400, plastic track detectors, LR 115 type-2 and CR-39) techniques using a standard source. The calibration constant is normally expressed in terms of cpm or tracks/mm^2 hr per Ci/ml.

THEORY

The standard solution of 0.0108 μCi was prepared from 5.4 μCi $RaCl_2$ solution by diluting it in freshly distilled water and was kept undisturbed for 4 weeks period in order to establish an equilibrium between Ra(226) and Rn(222). In such a closed system with liquid-gaseous inter phase, the radon distribution between two phases follows Henry's law (Alekseev et al., 1959)

$$\frac{N_1}{V_1} = \frac{N_2}{V_2} S_t \qquad \ldots \quad (1)$$

where N_1 is the quantity of radon in liquid phase, N_2 the quantity of radon in gaseous phase, V_1 the volume of liquid, V_2 the volume of gas, and S_t^2 the solubility constant which is governed by the formula:

$$S_t = 0.106 + 0.405 \exp(-0.050t) \qquad \ldots \qquad (2)$$

where t is the temperature in $^{\circ}C$.

The activity of standard corresponding to the quantity of radon (N_1+N_2) being known, the individual values of N_1 and N_2 can be calculated from the known values of V_1 and V_2 by using eq.1.

EXPERIMENTAL

In the radon emanometer (Type RMS-10) the detector is an air-tight cylindrical chamber (110 ml) viz. scintillation cell, whose walls are coated with silver-activated zinc sulphide phosphor. Alpha particles emitted from radon and its decay product produce scintillations which are recorded by scintillation assembly consisting of PMT and a scaler unit. The scintillation cell is connected to the standard $RaCl_2$ solution which is assumed to have attained the radioactive equilibrium conditions. The radon gas is de-emanated from the solution by bubbling air through it with the hand-operated rubber pump (Fig.1). The detector ends are clamped and the count rate is recorded after 4 hrs.

In alphameter-400, the detector is silicon-diffused junction with an active area of 400 mm^2. The standard $RaCl_2$ solution is kept below the detector chamber. When the alpha particles enter the n-p junction, a number of electron-hole pairs are generated, the number being proportional to the energy of alpha particles. The resulting display of counts per minute is related with known radon concentration in $RaCl_2$ solution.

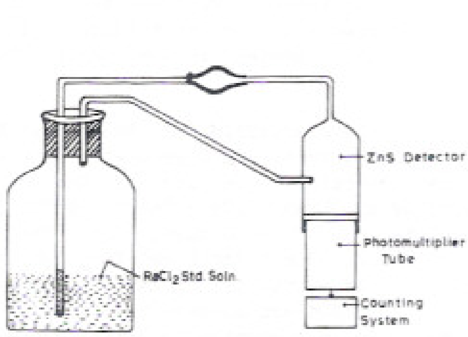

Fig.1. Apparatus for calibrating the ZnS(Ag) detector.

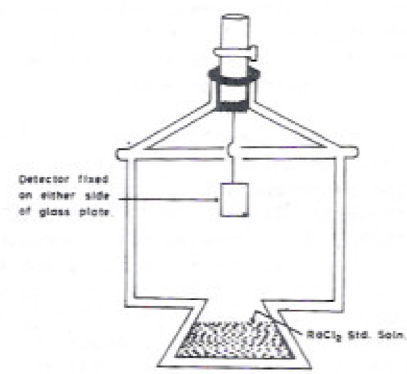

Fig.2. Desiccator containing standard $RaCl_2$ solution.

Two different types of alpha-sensitive plastic track detectors are used in this experiment, viz. cellulose nitrate (LR-115 Type-2) and polycarbonate (CR-39). LR-115 Type 2 has a thin layer of 12 µm red cellulose nitrate coated on the 100 µm thick polyster base. CR-39 polycarbonate sheets were obtained from different suppliers (Pershore Moulding Ltd., U.K., MOM-Atomki, Hungry and Homalite Corporation, USA). The plastic films fixed on either side of the microslide were suspended at the centre of the desiccator having standard $RaCl_2$ solution (Fig. 2). The detector samples were kept 10 cm away from the surface of solution and walls of dessicator to avoid the direct alpha radiations due to other possible alpha emitters. After an exposure of 24 hrs, these films were etched with NaOH soultion and scanned for recording the track density. The number of tracks/mm^2 is directly correlated with known radon concentration.

RESULTS AND DISCUSSION

The growth of Rn(222) activity from the freshly prepared $RaCl_2$ solution measured with Alpha meter-400 is illustrated in Fig.3. The secular equilibrium between Ra(226) and Rn(222) in the solution is established in 4 weeks period. The scintillation cell is filled with radon gas from this solution. The variation of the alpha activity in the cell with time is given in Fig-4. The constant increase in alpha activity is due to the growth of radon's daughter products which are also radioactive. The quilibrium between the growth and decay of radon's daughter products is attained in 3 hrs. The alpha activity in the cell begins to decrease after this period due to the decay of the daughter products. Hence for practical application of the technique for uranium exploration the count rate in the detector cell should be taken after 3-4 hrs of filling the cell in the field.

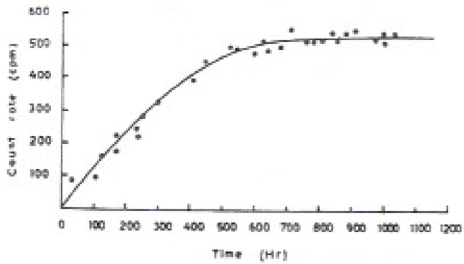

Fig.3. Plot of alpha count rate as a function of time.

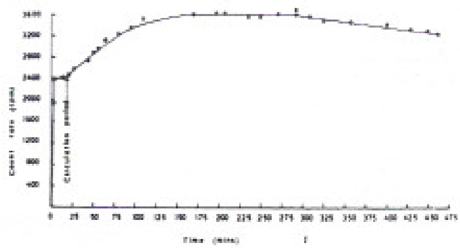

Fig.4. Variation of alpha count rate during and after bubbling air through $RaCl_2$ Solution.

The calibration factors for different detectors are given in Table 1. The activities of 0.003 pCi/ml and 0.240 pCi/ml are found to correspond to 1 count/ min in Radon Measuring System Type RMS-10 and Alphameter-400, respectively. The average activity required to register 1 track/mm^2 hr is 2.23 pCi/ml for LR-115 Type 2 (Kodak Pathe). 0.96 pCi/ml for CR-39, (Pershore Moulding) 1.40 pCi/ml for CR-39 Type MA-ND/ (MOM-Atomki) and 1.55 pCi/ml for CR-39 (Homalite Corporation) plastic track detector.

Table 1: Calibration constants for Radon detectors

S.No.	Name of Detectors	Manufacturer	Sensitivity	Eq.Activity pCi / ml
1.	ZnS (Ag) (Radon Emanometer)	Atomic Minerals Division, (DAE), Hyderabad, India.	1 cpm	0.003
2.	Silicon diffused Junction (Alphameter-400A)	Alpha Nuclear Toronto, Canada.	1 cpm	0.240
3.	LR-115 Type 2 (Cellolose Nitrate Plastic Film)	Kodak Pathe, Paris, France.	1 Track $mm^{-2}hr^{-1}$	2.232
4.	CR-39 (Polycarbonate)	Pershore Moulding Ltd., Worces, U.K.	1 Track $mm^{-2}hr^{-1}$	0.990
5.	CR-39 Type MA-ND/	MOM-Atomki Debrecen Hungry.	1 Track $mm^{-2}hr^{-1}$	1.410
6.	CR-39	Homalite Corporation, Wilmington, U.S.A.	1 Track $mm^{-2}hr^{-1}$	1.550

REFERENCES

Alekseev, V.V., A.G. Grammakov, A.I. Nikonov, and G.P. Tafeev (1959). Trans. series, USAEC Report tr., 3738.

Dyck, W. (1969). Geological Survey of Canada, Paper 68-21.

Fleischer, R.L., and R.S. Likes (1979). Terradex Corporation, Report No. 79CRD020.

Gingrich, J.E., and J.C.Fischer (1976). IAEA Vienna, 213.

Pacer, J.C., and R.F. Czarnecki (1980). The U.S. Deptt. of Energy GJBX-177.

Singh, M., N.P.Singh, S.Singh, and H.S.Virk (1984). Nucl. Tracks and Rad. Meas., 8, 415-418.

Tewari, S.G., P.C.Ghosh, and A.S. Bhatnagar (1968). Ind. J.Pure and Appl. Phys., 6, 33-36.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance by CSIR, New Delhi. They are thankful to Dr. P.C.Ghosh, Scientific Officer (S.F.), Department of Atomic Energy, Hyderabad for helpful discussions and supply of LR-115 plastic sheets.