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Radon in soil and its concentration in the atmosphere around Mysore city, India

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Abstract : Radon concentration in soil-gas and in the atmospheric air has been studied around Mysore city (12°N and 76°E) using Solid State Nuclear Track Detectors. The radon in soil-gas is found to be higher at a depth of 1 m than at a depth of 0.5 m from the ground surface. The higher radon concentration in soil was observed near Chamundi Hills and Karigatta village with average values of 5.94 kBq.m^{-3} and 5.32 kBq.m^{-3} at 1 m depth from the ground surface. Seasonal variations in radon in soil gas shows that, the concentration is lower in summer with an average value of 0.60 kBq.m^{-3} and higher in monsoon season with an average value of 4.70 kBq.m^{-3}. Estimation of ^{226}Ra in soil at these locations is also made using HPGe detector. The activity of ^{226}Ra, varies from 4.82 to 74.23 Bq.kg^{-1} with an average value of 32.11 Bq.kg^{-1}. Radon concentrations in soil-gas shows good correlation with the activity of ^{226}Ra in soil with a correlation coefficient of 0.76

Keywords : SSNTD, scintillometer, radiation dose, Mysore city.

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1. Introduction

Radon is one of the naturally occurring radioactive elements in the environment produced from the radioactive decay of radium isotopes, which are the decay products of ^{238}U, ^{232}Th and ^{235}U. Hence the concentrations of uranium and thorium in the bedrock and soil materials determine the amount of radon produced in the soil. The radon produced in the soil migrates through the mechanism of emanation, diffusion and convection through pore spaces in soil, fractures in rocks and along with weak zones such as shear, faults, thrust *etc.* [1–3]. For some geological situations, radon migrates long distances from its place of origin and can be detected by alpha particle recorders at the earth surface [2,3]. This rate of migration is affected by many factors, such as distribution of ^{226}Ra in the soil and bedrock, soil porosity, micro-cracks of bedrock, rainfall, air temperature, barometric pressure and surface winds [4,5]. The fraction of radon atoms released into a rock or soil pore space from a ^{226}Ra bearing grain is

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expressed in terms of 'radon emanation coefficient', which is mainly affected by the size of soil grain and soil moisture condition [6]. Radon transportation takes place in the communicating pore space generally directed to the earth's surface and are then transported by diffusion and advection through this space until they decay or are released into the atmosphere [7]. Radon concentration of an area is governed by the radium content in the minerals, the radon emanating power in the materials, the permeability of the soil and the underlying rock and the moisture content of the soil [8]. Moisture content in soil can increase radon emanation but if the soil pores become saturated emission is inhibited [1].

Radon and its progeny are responsible for about 45% of the exposure of the world population to ionizing radiation from natural sources [1,9–11]. The estimation of radon in the soil-gas and in atmosphere has been suggested as a tool for many investigations such as exploration for uranium, earthquake prediction, groundwater transport and geothermal resource assessments [12,13].

2. Materials and methods

2.1. Radon and its progeny concentration :

Solid State Nuclear Track Detectors (SSNTD) have been extensively used to perform integrated measurements of radon in soil [14–18]. The experimental set up for radon monitoring in the soil is shown in Figure 1. SSNTD based twin cup dosimeters developed and standardized at Bhabha Atomic Research Centre (BARC) were used for the measurement [18–20].

For the measurement of radon in soil, the cup was inserted in a 1 m long PVC pipe closed at the top. The radon concentration was obtained at 0.5 and 1 m depth in soil. The PVC tube was inserted through bore holes of 7 cm in diameter drilled to 0.6 m and 1.1 m depth in the ground. For the measurement of ^{222}Rn and its progeny concentrations at a height of 2 m from the ground surface, the dosimeter was mounted inside an inverted 1-liter plastic cylinder on protection against direct sunlight and a nylon stocking covered the entire assembly to protect the dust filter from insects.

At the end of the stipulated period of exposure, usually about 90 days, the dosimeters were retrieved and SSNTDs were etched in 10% NaOH solutions for 1 hour at 60°C. At each location the measurement was done on a time integrated quarterly cycles to cover the four seasons of a calendar year. The tracks were counted using spark counter and the radon and its progeny concentrations are calculated by the following relations [19].

$$C_R(\text{Bq.m}^{-3}) = \frac{T_m}{d.S_m} \quad (1)$$

where C_R = radon gas concentration (Bq.m^{-3}), t_m = Track density of the film in

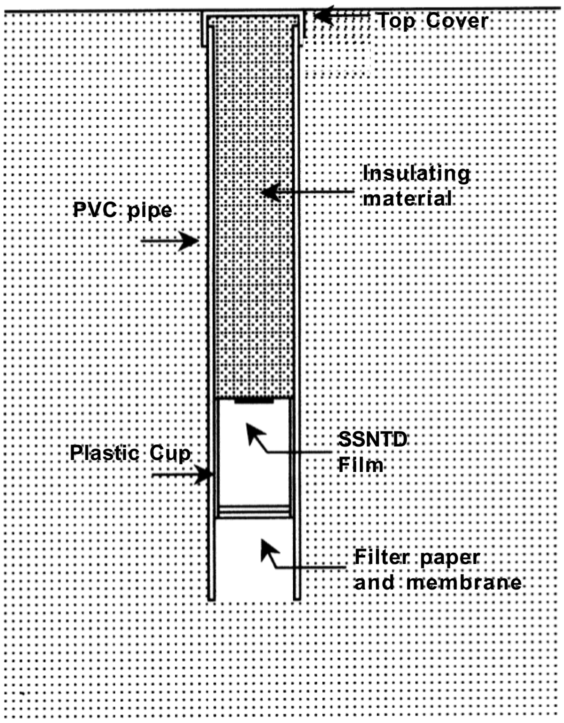

Figure 1. Experimental setup for soil-gas measurements.

membrane compartment (tracks cm^{-2}), d = period of exposure (days) and S_m = sensitivity factor for radon in membrane compartment (tracks cm^{-2} per Bq.d.m^{-3})

$$R_N(\text{mWL}) = \frac{C_R F_R}{3.7} \tag{2}$$

where R_N = radon progeny concentration (mWL) and F_R = equilibrium factor for radon.

The inhalation dose due to radon and its progeny is calculated by using the conversion coefficient 9 nSv (Bq.h.m^{-3})$^{-1}$, equilibrium factor 0.6 and outdoor occupancy factor 1760 h. The dose coefficient for radon dissolved in blood is calculated using conversion coefficient 0.17 nSv (Bq.h.m^{-3})$^{-1}$ following the inhalation intake. Finally an estimation of the effective dose (m Sv.y^{-1}) is estimated by using the formula [1].

$$\text{Dose} = [0.17 + 9 \times 0.6] C_R \times 1760 \times 10^{-6} \tag{3}$$

2.2. Estimation of ^{226}Ra in soil samples :

The activity of ^{226}Ra in the soil collected at several locations is measured using HPGe detector following standard procedure [21,22].

2.3. Ambient gamma level :

The ambient gamma radiation levels were measured using Scintillometer. The measurements were carried out in the outdoor during the installation and retrieval of the radon dosimeter at all locations. All measurements were made one meter above the ground level. The arithmetic mean of the about 100 readings was taken as representative figure for each location.

3. Results and discussions

Table 1 shows the variation of radon in soil-gas in different seasons of a year measured at different places around Mysore city and ^{226}Ra content in the soil at these locations. Lower concentration is observed in summer season which varies from 0.13 to 1.74 $kBq.m^{-3}$ with an average value of 0.60 $kBq.m^{-3}$ and higher concentration is observed in monsoon which varies from 0.95 to 13.14 $kBq.m^{-3}$ with an average value of 4.70 $kBq.m^{-3}$.

Table 1. Seasonal variation of radon concentration in soil.

Locations	^{226}Ra ($Bq.kg^{-1}$)	Depth (m)	Radon concentration in soil ($kBq.m^{-3}$) Winter	Summer	Monoon	Autumn	Average
Department of Physics	20.32	0.5	3.69	0.27	3.54	2.34	2.46
		1.0	4.73	0.45	4.18	3.71	3.27
Baburayana Koppalu	11.90	0.5	4.38	0.26	3.34	0.90	2.22
		1.0	4.89	0.51	4.63	2.29	3.08
Naguvana Halli	13.00	0.5	1.26	0.13	0.95	0.49	0.70
		1.0	1.00	0.34	1.16	0.39	0.72
Vijaya Nagara	4.82	0.5	2.80	0.39	1.49	1.53	1.55
		1.0	3.44	0.36	2.81	2.56	2.29
Chamundi Hill	70.29	0.5	3.63	0.80	10.42	2.06	4.23
		1.0	4.98	1.40	13.14	4.22	5.94
Karigatta	51.09	0.5	2.19	0.36	4.71	1.38	2.16
		1.0	3.25	1.08	9.91	7.03	5.32
Yelwala	74.23	0.5	2.46	0.54	4.02	1.54	2.14
		1.0	2.75	1.74	6.02	2.28	3.20
Thuruganur	11.26	0.5	1.10	0.60	2.28	1.01	1.25
		1.0	1.71	0.33	2.62	1.01	1.42
Average	32.11		3.02	0.60	4.70	2.17	2.62

Higher radon concentration in soil-gas was observed at Chamundi Hills and Karigatta village with an average value of 5.94 and 5.32 $kBq.m^{-3}$ at 1.0 m depth from the ground surface. Where as lower radon concentration in soil-gas was observed at Naguvana Halli with an average value of 0.72 $kBq.m^{-3}$ at 1.0 m depth from the ground surface. The higher values in Chamundi Hills and Karigatta village may be due to higher ^{226}Ra concentration in soil at these places. ^{226}Ra concentration at Chamundi Hills and

Karigatta is 70.29 and 51.09 $Bq.kg^{-1}$ and at Naguvanahalli it is found to be 13.00 $Bq.kg^{-1}$. Variation ^{222}Rn in soil-gas with ^{226}Ra in soil is shown in Figure 2. Radon concentration in soil-gas shows good correlation with the activity of coefficient of 0.76.

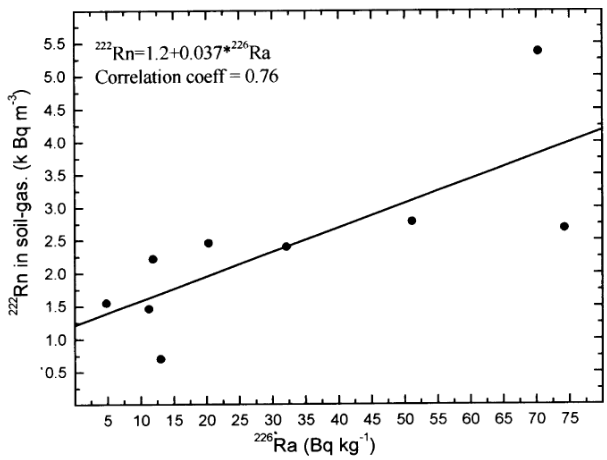

Figure 2. Variation ^{222}Rn in soil-gas.

The variation of radon in soil, gamma dose rate, ^{222}Rn, its progeny concentration and inhalation dose due to radon and its progeny in different locations around Mysore city are shown in Table 2. Radon concentration varies at these locations from 20.3 to 52.86 $Bq.m^{-3}$ with an average value of 31.25 $Bq.m^{-3}$, radon progeny concentration varies from 0.09 mWL to 3.92 mWL with an average value of 1.38 mWL and gamma exposure rate varies from 0.009 to 0.018 $mR.h^{-1}$ with an average value of 0.012 $mR.h^{-1}$. A good correlation has been observed between radon in soil-gas and gamma

Table 2. Variation of gamma dose rate, radon in soil-gas, and ^{222}Rn and its progeny concentrations in the atmosphere and inhalation dose.

Location	Gamma dose rate ($mR.h^{-1}$)	^{222}Rn in soil-gas ($kBq.m^{-3}$)		^{222}Rn in atmosphere ($Bq.m^{-3}$)	^{222}Rn progency in atmospehre (mWL)	Dose (mSv/y^1)
		0.5 m	0.1 m			
Physics department	0.010	2.46	3.27	16.95	2.96	0.17
Baburayana Koppalu	0.010	2.22	3.08	35.65	0.13	0.35
Naguvana Halli	0.011	0.70	0.72	52.85	0.33	0.52
Vijaya Nagara	0.009	1.55	2.29	20.3	0.41	0.20
Chamundi Hills	0.018	4.23	5.94	26.9	3.11	0.26
Karigatta	0.010	2.16	5.32	45.15	3.92	0.44
Yelwala	0.012	2.14	3.20	25.25	0.09	0.25
Thuruganur	0.012	1.25	1.42	26.95	0.10	0.26
Average	0.012	2.08	3.15	31.25	1.38	0.31

exposure rate with a correlation coefficient of 0.78. The inhalation dose due to radon and its progeny concentration at these locations varies from 0.20 to 0.52 $mSv.y^{-1}$ with an average value of 0.31 $mSv.y^{-1}$.

4. Conclusions

The activity of ^{226}Ra in soil, radon in soil-gas, radon and its progeny concentrations in the atmosphere were studied around Mysore city. The radon in soil-gas is found to be higher at a depth of 1 m compared to that at a depth of 0.5 m from the ground surface. The higher radon concentration in soil was observed near Chamundi hills and Karigatta village with average values of 5.94 $kBq.m^{-3}$ and 5.32 $kBq.m^{-3}$ at 1 m depth from the ground surface. Seasonal variations in radon in soil gas shows that, the concentration is lower with an average value of 0.60 $kBq.m^{-3}$ and higher in monsoon season with an average value of 4.70 $kBq.m^{-3}$. The activity of ^{226}Ra, varies form 4.82 to 74.23 $Bq.kg^{-1}$ with an average value of 32.11 $Bq.kg^{-1}$. Radon concentrations in soil-gas shows good correlation with the activity of ^{226}Ra in soil with a correlation coefficient of 0.76.

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References

[1] UNSCEAR Report to the General Assembly with Scientific Annexes, United Nations, **Annexure B** 97 (2000)

[2] R L Fleischer and A Mogro-Campero *J. Geophys. Res.* **83** 3539 (1978)

[3] C W Horton and I T Rogers (Jr.) *J. Appl. Phys.* **16** 367 (1945)

[4] Murat Inceoz, Oktay Baykara, Ercan Aksoy and Mahmut Dogru *Radiat. Meas.* **41** 349 (2006)

[5] Serena Righi and Luigi Bruzzi *J. Environ. Radioactivity* **88** 158 (2006)

[6] C Baixeras, B Erlandsson, L L Font and G Jonsson *Radiat. Meas.* **34** 441 (2001)

[7] Kainan SUN, Qiuju GUO and Wchihai ZHUO *J. Nucl. Science Technology* **41** 86 (2004)

[8] F K Sheng and H S Jer *Pure Appl. Geophys.* **160** 75 (2003)

[9] E M Durrance *Radioactivity in Geology : Principles and Applications.* (New York : Ellis Horwood Ltd. Publishers, John Wiley) (1986)

[10] L L Quirino, J M Soriano, F Mireles, J I Davila, H Lopez, J L Pinedo and C Rios *Appl. Radiat. Iso.* **65** 371 (2007)

[11] J H Lubin and J D Boice *J. The National Cancer Institute* **89** 49 (1997)

[12] R C Ramola, M S Kandri and R B S Rawat *Curr. Sci.* **73** 771 (1997)

[13] F S Erees, G Yener, M Salk and O Ozbal *Radiat. Meas.* **41** 354 (2006)

[14] N Segovia, P Pena and E Tamex *Nucl. Tracks Radiat. Meas.* **19** 405 (1991)

[15] P Pena, N Segovia, J Azorin and M Mena *J. Radioanalytical Nucl. Chem.* **247** 39 (2001)

[16] V M Choubey, R C Ramola and K K Sharma *Nucl. Geophys.* **8** 49 (1994)

[17] F Ruckerbaur and R Winkler *Appl. Radiat. Iso.* **55** 273 (2001)

[18] TV Ramachandran, B Y Lalit and U C Mishra *Nuclear Tracks Radiat. Meas.* **13** 81 (1987)

[19] Y S Mayya, K P Eappan and K S V Nambi *Radiat. Prot. Dosim.* **77** 177 (1998)

[20] Wafaa Arafa *Radiat Meas.* **35** 207 (2002)

[21] *EML Procedure manuals*, 26-th (eds.) H L Volchok and G Planque (New York : Environmental Measurement Laboratory) (1983)

[22] IAEA/RCA *Health Phys. Division.* (BARC : Kalpakkam, India) **85** (1989)