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Radon measurements using lr-115 plastic track detectors

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ABSTRACT

Radon concentrations were measured using LR-115 plastic track detectors in some of the dwellings of Bangalore, India. The levels of radon concentrations are relatively high in poor ventilated houses than in well ventilated houses in all the selected areas. The arithmetic mean with standard deviation of the ^{222}Rn concentrations in Malleshwarum, Sheshadripurum, Jayanagar and Srirampurum are 58.46 ± 2.92, 53.57± 2.67, 39.43± 1.97 and 48.59 ± 2.42 Bq m^{-3} respectively. The higher concentration of ^{222}Rn is observed in Sheshadripurum and lower concentration of 39.43Bq m^{-3} was observed for Jayanagar. This paper presents the preliminary results of the work.

KEYWORDS

Radon;
Thoron;
Wall;
SSNTD.

INTRODUCTION

Overall as a global average not less than 80% of the radon emitted into the atmosphere comes from the top layers of ground. The radon emanation is associated with the presence of radium and its ultimate precursor uranium in the ground. Although these elements occur virtually in all types of rock and soil, their amounts vary with the specific site and geological material. Uranium is one of the most widely spread of all of the elements. It occurs, with considerable variation. It is present in all rocks and soil and therefore in most of the raw materials from which we process finished products. As a result, its daughter, radium, is also widely spread, particularly in those products which are made from mineral products. Radium, with a half-life of 1600 years, continuously generates its immediate daughter, radon. Radon, being a noble gas with a half-life of 3.82 days, can diffuse for some distance through porous materials before decaying to its short lived daughters. When it is generated in or near to buildings, it can diffuse into living spaces. The concentration of radon and its daughters in living spaces depends on the balance between the rate at which they are removed from the air and the rate at which they are introduced. Exposure to radon gas, which is present naturally in the environment, constitutes over half the radiation dose received by the public annually. Inhalation of radon and its daughter products can cause a significant health hazard when they are present in enhanced levels in enclosed indoor environment like human dwellings, if it is poorly ventilated and if the radon input from the soil and building materials is high. Plastic track detectors have been used to measure indoor radon levels. The average radon

concentration in most of the dwellings falls in the range of the action level recommended by the International Commission on Radiological Protection.

Study area

Location selected for the study is Bangalore Urban district that is situated in the south-eastern part of Karnataka State. It has an aerial extent of about 2200 square kilometers and population of around six millions. The district lies between the latitudes $12^0$39' to $13^0$3' N and longitudes $77^0$22' to$77^0$52' E. The climate is having four distinct seasons. April is usually the hottest month with the mean daily maximum temperature of 30-35^{0}C and mean daily minimum at 20-24^{0}C. Relative humidity is high during the Rainy season for the South-West Monsoon months and decreases thereafter. During the months from May to September, the winds are west to South-West to West, while during the period from November to March, they are east to North-East and East to South-East. The year is divided into four season's viz.:

1. Summer season from March to the end of May
2. Rainy season from June to September
3. Autumn season from October to November and
4. Cold season from December to January

Methodology

The concentrations of radon, thoron and their progeny in dwellings are measured using Solid State Nuclear Track Detectors (SSNTD), which are thin sheets of dielectric materials such as cellulose nitrate and polycarbonate. SSNTDs are sensitive to alpha but not to beta and gamma radiation. An alpha particle passing through such an insulating media will leave narrow trail of damage and the damage produces broken molecular chains, free radical etc. These damaged regions can dissolve at a much higher rate than the undamaged material in certain chemical agents called enchants. The dissolved portion appears as a track in the film. The number of such tracks gives the number of alpha particles. The dosimeters are constructed using SSNTDs. The dosimeter used is a cylindrical plastic cup divided into two components having a provision for holding the SSNTD films in specific concentration. The SSNTD is a cup with a suitable membrane like thin latex rubber sheet that determines the ^{222}Rn concentration alone since ^{220}Rn gas is trapped to less than 1% and SSNTD inside the cup with a filter paper determines the both ^{222}Rn and ^{220}Rn concentrations in air. The system used for these measurements is called double chamber dosimeter. The bare mode exposure film can be fixed conveniently on the surface of the chamber. For indoor measurements normally LR-115 plastic track detectors are preferred[1-4].

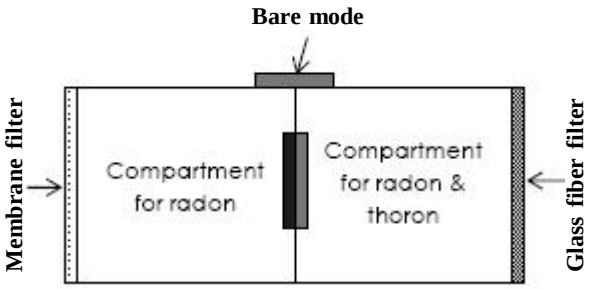

Figure 1: Entrenched outlook of Twin cup dosimeter

The schematic representation of the double chamber dosimeter cup used in the study is shown in figure 1. The chamber has cylindrical in shape and has the dimension with 45 mm and 62 mm of length and diameter, respectively. The films used in the dosimeter are of approximately 12 μm thickness. The SSNTD-1 placed in compartment-A measures only radon, which diffuses into it from the ambient air through a semi-permeable membrane such as latex, cellulose, nitrate etc. These membranes have good permeability of the order of $10^{12} – 10^{-11}$ m^2 s^{-1} and allow more than 95% of radon gas to diffuse, and reduce thoron concentration to the extent of 1% or even less[5]. On the opposite side, the glass fiber filter paper in the compartment-B allows both radon and thoron gas to diffuse in and hence the tracks on SSNTD-2 are measure of concentration of both the gases. The SSNTD-3 exposed in the bare mode that is placed on the outer surface of the dosimeter registers alpha tracks attributable to the airborne concentrations of both the gases and their progeny[6]. These dosimeters are suspended from the midpoint of the house at a height of approximately 2 m from the floor of the dwelling. At the end of the stipulated period of exposure, usually 90 days, the dosimeters are retrieved and all the three SSNTD's are etched with 10% NaOH solution for one hour where the temperature of the bath is maintained at 60^{0}C[7]. The track density of alphas in the film is determined using a spark counter. This exposure cycle has been extended in a time integrated four quarterly cycles to cover all the four seasons of a calendar year to evaluate the annual radon/thoron and their progeny

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TABLE 1: ^{222}Rn concentrations from different walls (Bq m^{-3}) in the dwellings of Malleshwarum

Number of windows	Type of ventilation	Position of the dosimeter in the room from the entry					Arithmetic mean
		Wall L	Wall R	Wall F	Wall B	Center C	
0	Poor	93.18±4.65	92.98±4.64	72.81±3.64	91.87±4.49	67.37±3.36	83.64±4.18
1	Partial	66.21±3.31	79.47±3.97	65.85±3.29	75.38±3.76	55.38±2.76	68.45±3.42
2	Moderate	53.39±2.66	59.47±2.97	52.69±2.63	49.67±2.48	42.93±2.14	51.63±2.58
3	Well	27.54±1.37	32.98±1.64	30.88±1.54	33.83±1.69	26.84±1.34	30.14±1.50

Average indoor ^{222}Rn concentration in Malleshwarum is 58.46 ± 2.92Bq m^{-3}

TABLE 2: ^{222}Rn concentrations from different walls (Bqm^{-3}) in dwellings of Sheshadripurum

Number of windows	Type of ventilation	Position of the Dosimeter in the room					Arithmetic mean
		Wall L	Wall R	Wall F	Wall B	Center C	
0	Poor	90.23±4.51	72.92±3.64	98.76±4.93	67.84±3.39	45.03±2.25	76.91±3.84
1	Partial	52.63±2.63	48.89±2.44	85.81±4.29	57.25±2.86	35.67±1.78	56.05±2.80
2	Moderate	39.18±1.95	36.56±1.82	67.84±3.39	51.99±2.59	33.33±1.66	45.78±2.28
3	Well	28.65±1.43	28.33±1.41	47.25±2.36	42.63±2.13	21.05±1.05	35.57±1.77

Average indoor ^{222}Rn concentration in Sheshadripurum is 53.57± 2.67Bq m^{-3}

TABLE 3 : ^{222}Rn concentrations from different walls (Bq m^{-3}) in the dwellings of Jayanagar

Number of windows	Ventilation type	^{222}Rn concentrations from different walls (Bq m^{-3})					Arithmetic mean value
		Wall L	Wall R	Wall F	Wall B	Center C	
0	Poor ventilation	37.33±1.86	24.56±1.22	49.16±2.45	67.84±3.39	43.93±2.19	44.56±2.22
1	Partial ventilation	34.97±1.74	23.71±1.18	45.19±2.25	61.25±3.06	41.99±2.09	41.22±2.06
2	Moderate ventilation	32.17±1.60	22.81±1.14	44.44±2.22	55.93±2.79	38.29±1.91	38.72±1.93
3	Well ventilation	30.99±1.54	22.56±1.12	40.94±2.04	38.48±1.92	33.27±1.66	33.24±1.66

Average indoor ^{222}Rn concentration in Jayanagar is 39.43± 1.97Bq m^{-3}

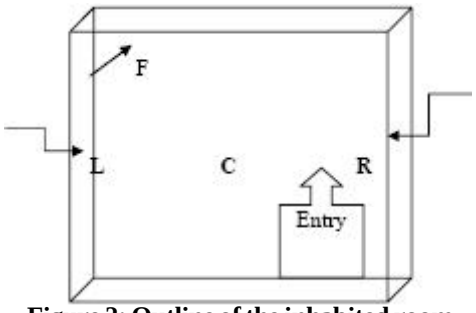

Figure 2: Outline of the inhabited room

levels.

The radon/thoron levels and their progeny working level concentrations are estimated by the following relations[6].

$$C_R\ (Bq\ m^{-3}) = T_m / (d\ S_m)$$

$$C_T\ (Bqm^{-3}) = (T_f - d\ C_R\ S_{rf}) / (d\ S_{rf})$$

where T_m is the track density of the film in membrane compartment, d is the period of exposure in days, S_m refers to the sensitivity factor of membrane compartment, T_f is the track density of the film in filter compartment, S_{rf} is the Sensitivity of ^{222}Rn in filter compartment, and, C_R and C_T is the concentration of ^{222}Rn and ^{220}Rn, respectively.

$$R_n\ (m\ WL) = (C_R\ F_R) / 3.7$$

$$R_T\ (m\ WL) = (C_T\ F_T) / 0.275$$

Where R_n and R_T refers to the progeny concentrations of ^{222}Rn and ^{220}Rn, respectively.

$$F_R = 0.104\ f_{RA} + 0.518\ f_{RB} + 0.37\ f_{RC}$$

$$F_T = 0.91\ f_{TB} + 0.09\ f_{TC}$$

where f_{RA}, f_{RB} and f_{RC} are the activity fractions with respect to parent gas. But, F_R and F_T represents the equilibrium factors for ^{222}Rn and ^{220}Rn progeny corresponding to the extracted ventilation rate[6]. Equilibrium factor is determined using the working level concentrations, and the inhalation dose rates (m Sv y^{-1}) is estimated by using UNSCEAR[8].

$$D = 7\times[(0.17 + 9F_R)\ C_R + (0.11 + 32F_T)\ C_T] \times 10^{-3}]$$

RESULTS AND DISCUSSIONS

^{222}Rn concentration in different walls

An attempt has been made to study the radon concentrations in different dwellings of different locations of Bangalore city, India. The details of results obtained are tabulated in TABLES 1-4. The different walls of the room in various locations are specified as L, R, F and B for left, right, front, back walls respectively and the center of the room as C and this is clearly shown in figure 2. The concentration shows wide range of variation between x and y for the studied area. The arithmetic mean of ^{222}Rn concentration in Malleshwarum, Sheshadripurum, Jayanagar and Srirampurum are 58.46

TABLE 4: ^{222}Rn concentrations from different walls (Bq m^{-3}) in the dwellings of srirampurum

Number of windows	Ventilation Type	Position of the dosimeter in the room					Arithmetic mean value
		Wall L	Wall R	Wall F	Wall B	Center C	
0	Poor ventilation	69.93±3.49	65.19±3.25	58.25±2.91	63.71±3.18	63.72±3.18	64.16±3.20
1	Partial ventilation	58.48±2.92	59.16±2.95	46.97±2.34	50.37±2.51	53.00±2.65	53.51±2.67
2	Moderate ventilation	47.25±2.36	45.93±2.29	35.37±1.76	32.16±1.60	39.64±1.98	40.07±2.00
3	Well ventilation	37.84±1.89	52.05±2.60	30.94±1.54	25.93±1.29	36.34±1.81	36.62±1.83

Average indoor 222Rn concentration in Srirampurum is 48.59±2.42 Bq m-3

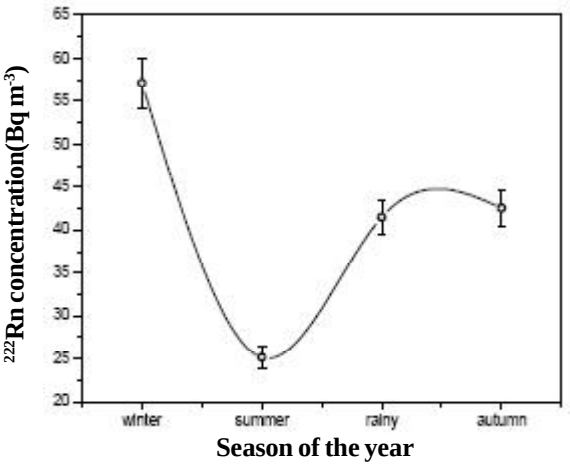

Figure 3: Seasonal variations of ^{222}Rn concentrations

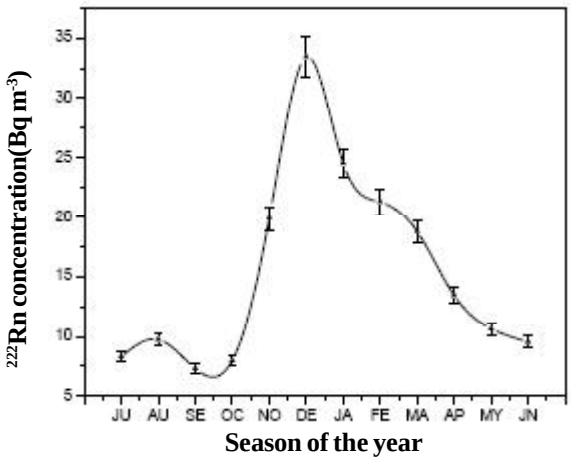

Figure 4: Monthly variation of indoor ^{222}Rn concentrations

± 2.92, 53.57± 2.67, 39.43± 1.97 and 48.59 ± 2.42 Bqm^{-3}, respectively. The higher concentration of ^{222}Rn is observed in Sheshadripurum and may be due to the presence of uranium prospects beneath the soil[9]. The lower concentration of 39.43± 1.97 Bqm^{-3} was observed for Jayanagar and this may be attributed to the fact that the majority of the houses had good ventilation[10]. ^{222}Rn concentration is found to vary from wall to wall and the variation may be due to the random distribution of radioactive rock species used ignorantly in the construction of the houses[11,12]. The concentration at the center of the room was found to be quite low compared to that on the walls. From the data obtained, it is evident that the radon concentration is low compared to the concentrations in the poor ventilated houses. The reason being is that in well ventilated houses windows will be operated frequently as and when required. The ^{222}Rn concentration recorded in the dwellings of Bangalore city are well within the limit recommended by International Commission for Radiation Protection.

Monthly/Seasonal variations

^{222}Rn, ^{220}Rn and their progeny levels in different locations of Bangalore city are measured during 2007-2008. All the houses chosen were built with local bricks and the cement on the ground floor. The average monthly variation of indoor radon is shown below in the figure 3. It shows the general trend of variation in the ^{222}Rn and its daughter concentrations in the houses. The set of behavior of ^{222}Rn and its daughter concentrations in indoor air of some of the dwellings of Bangalore city, with a peak during winter period of December to January and it is well documented by several other researchers[13-16] and is essentially influenced by the intensive temperature inversion which occurs in winter, the vertical mixing and dispersion which occur in summer and the rain wash out during monsoon. The monthly variations of ^{222}Rn progeny concentrations are shown in figure 4. December shows maximum concentration and minimum is observed in the month of June. The figure 5 shows the annual average concentrations of ^{222}Rn during winter, summer, rainy and autumn seasons and the values are 57.13, 25.17, 41.49 and 42.57 Bqm^{-3}, respectively. Annual average ^{222}Rn progeny concentrations for winter, summer, rainy and autumn seasons are found to be 1.15, 0.153, 0.438 and 0.506 mWL respectively. The ventilation rate is presumably reduced during winter, particularly night, where there is a con-

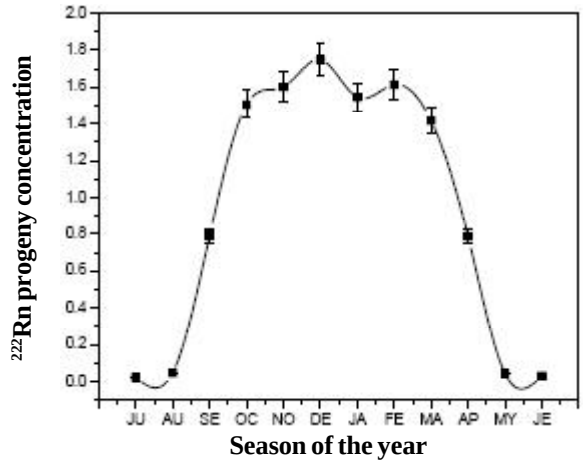

Figure 5: Monthly variation of indoor ^{222}Rn progeny concentrations

siderably fall in ambient temperature and the doors and windows are closed more frequently and for more duration to avoid entry of cold air into the dwellings. Where as in summer in addition to the windows being open, air circulating fans are also used, resulting in better air exchange. This fact is particularly highlighted by[17] Fleischer (1989) as being responsible for indoor ventilation changes[18]. Ningappa et al.(2008) have done the studies on indoor radon and its progeny levels around Bangalore rural district and Baglaore city, and reported that the geometrical mean value of radon concentration level in indoor atmosphere of granite quarries varies from 55 Bq.m^{-3} to 300 Bq.m^{-3} with a median of 152.5 Bq.m^{-3} and its progeny varies from 0.24 to 19.6 mWL with a median of 8 mWL respectively. In Bangalore city the concentration level of radon varies from 18.4 Bq.m^{-3} to 104 Bq.m^{-3} with a median of 45 Bq.m^{-3} and its progeny varies from 1.62 to 11.24 mWL with a median of 4.78 mWL respectively. Higher concentration of radon and its progeny were observed in granite quarries compared to Bangalore city due to the mining activity and types of the bedrock in granite quarries.

Summary

Radon measurements in several dwellings are carried out and the annual mean indoor radon concentrations were obtained at 120 houses using SSNTD's. The indoor concentration lies in the range of the action level. The variation in the indoor radon concentration may be due the differences in the activity of uranium and thorium in the soil and the building material

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