Radiological Risk Assessment due to Radon and Thoron in the Dwellings of Peddamula Village, Nalgonda District, Telangana, India

G Suman[a], M Sreenath Reddy[b]*, K Vinay Kumar Reddy[c], Ch. Gopal Reddy[b,d] & P Yadagiri Reddy[b,d]

[a]Sreyas Institute of Engineering and Technology, Bandlaguda, Hyderabad 500 068, India

[b]Department of Physics, Osmania University, Hyderabad 500 007, India

[c]Department of Physics, Chaithanya Bharathi Institute of Technology, Hyderabad 500 075, India

[d]Department of Physics, Mahatma Gandhi University, Nalgonda 508 003, India

Radon and thoron are significant contributors for radiological risk in indoors and are originating from decay chain of uranium and thorium, which are prevalent in the environment. These concentrations in indoors depends on the presence of uranium and thorium concentration, and lifestyle of the habitants. The village "Peddamula" is located in the neighbourhood area of proposed mining for exploration of uranium. The estimated concentration of radon and thoron is found in the range 14- 448 Bq.m^{-3} with an average value of 120 ± 82 Bq.m^{-3} (GM 100Bq.m^{-3}), and vary from 7 to 452 Bq.m^{-3} with an average value of 154 ± 111 Bq.m^{-3} (GM 112Bq.m^{-3}), respectively. Computed the contribution to the effective dose per annum from, radon 3.02 mSv.y^{-1} and thoron is 4.32mSv.y^{-1}. In this paper the seasonal variation and distribution of ^{222}Rn and ^{220}Rn levels in the dwellings of the study area will be discussed.

Keywords: Decay chain; Effective dose; Radon; Thoron; Uranium; Thorium

1 Introduction

The ionizing nuclear radiation from natural sources on the earth is omnipresent and it is inescapable feature for human beings. Radon and thoron are significant contributors to the radiological risk in indoors and are originating in the uranium and thorium decay series, which are widespread in the environment[1]. The disintegration of ^{226}Ra produces radon ($T_{1/2}$ =3.8 days). The decay of ^{224}Ra produces the thoron, which has an exceptionally short $T_{1/2}$ = 55.6 s. The concentration of these radioactive gases in indoors depend on the presence of uranium and thorium concentration in the construction materials and lifestyle of the habitants. The radon and thoron in the outdoor environment get diluted instantaneously whereas in indoor environment it may be built up because of air moment restriction. The concentration of these gases exceeds a threshold value may result health hazards to habitants[2].The materials used in construction, dwellers lifestyle, geology, and meteorological situations are appreciably altering the ^{222}Rn and ^{220}Rn concentration in the indoor environment. The inhalation dose caused by these two radioactive gases and their progeny are significant in assessing the radiation risk at low doses in epidemiological studies.

The progeny of ^{222}Rn and ^{220}Rn are solid isotopes, such as polonium, bismuth and lead, that are to be attached with aerosols. The progenies of thoron pose a little more risk than that of the radon progeny because of their relative higher half-life and shows some extent carcinogenic effects[2]. The inhalation and exhalation of these gases in the indoors is a everlasting process, but however a small portion of radon and thoron remain in the respiratory track and begin to emit the alpha particles and may cause damage of tissues[3].The average effective dose annually is to be accounted 2.4mSv.y^{-1} from internal and external natural radiation origin, out of this 1.15mSv.y^{-1} dose is due to radon, thoron and its progeny[4]. During the last few decades, there is a growing awareness about the nuclear radiation risk caused by radon and thoron. The studies on the uranium mining workers envisage the risk due to radon isotopes and warranted scientific community globally on the estimation of radon isotope levels in the human abodes.

The preliminary survey conducted by the "Atomic Minerals Directorate for Exploration and Research" (AMDER) for the investigation of uranium confirms

the augmentation of ^{238}U, ^{232}Th, and ^{40}K elements in the present investigated area[5,6]. The 'Peddamula' is an interior village located in forest, is chosen to estimate the levels of natural radon isotopes in the indoors is due to its proximity with the proposed Chitrial uranium mineralized area and this is the first systematic study carried out.

2 Methods and Measurements

The radon isotopes "Radon and thoron" in the present study were estimated in the indoors using the passive and active techniques.

2.1 Passive technique

Among the different techniques, easily adoptable and integrated one is the "pinhole dosimeter technique," for the estimation of radon and thoron. This dosimeter comprises of two chambers. The dimension and description of pin-hole dosimeter with SSNTDs is familiar and the pictorial diagram of Pinhole Dosimeter (shown in Fig. 1[7]). Radon/thoron concentrations were measured using SSNTDs for integrated measurement, LR-115, Type-II detectors were chosen and these are pelliculable detectors (Kodak-pathe) consisting of cellulose nitrate with typical thickness of 12μm deposited on 100μm thick non etchable plastic base.

The pinhole dosimeters with SSNTDs were installed in the selected dwellings across the village. After specific time (3 months) of exposure, the SSNTDs were retrieved for further processing and installed again with fresh SSNTDs, and the same was
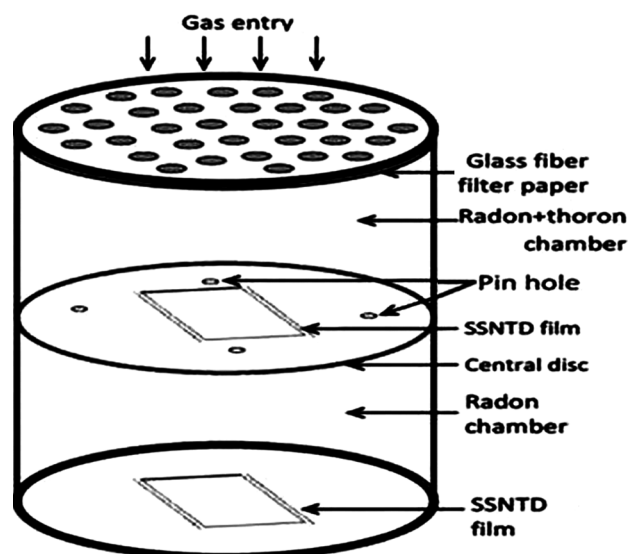

Fig. 1 — Pinhole Dosimeter.

repeated for four quarters in order to study the seasonal variation. The retrieved SSNTDs were etched chemically at 60 °C in a constant temperature bath for 90 min without stirring using a 2.5 N of NaOH solution to get the definite tracks. A spark counter was used to count the recorded tracks and the obtained tracks were converted into respective concentration (in Bq.m^{-3}) with the subsequent formulae.

$$C_R = T_1 / D * K_R \qquad \qquad \text{... (1)}$$

$$C_T = (T_2 - D * K_R * C_R)/(D * K_T) \qquad \text{... (2)}$$

Here, T_1 and T_2 are the number of tracks recorded owing to the radon and thoron, The days (D) of exposure of the film, K_R (calibration factor) for ^{222}Rn "(0.0170 ± 0.002 tr. cm.$^{-2}$ per Bq.d.m^{-3})" and K_T (calibration factor) for ^{220}Rn (0.010 ± 0.001 tr. cm^{-2} per Bq.d.m^{-3}).

The annual effective inhalation dose (mSv.y^{-1}) was calculated due to radon and thoron using formula.

$$EID(Radon) = EF \times C_{Rn} \times DCF(Rn) \times OF \quad \text{... (3)}$$

$$EID(Thoron) = EF \times C_{Tn} \times DCF(Tn) \times OF \quad \text{... (4)}$$

Where, C_{Rn} and C_{Tn} is the indoor radon and thoron (Bq·m^{-3}) activity. EF is 0.4 for radon and 0.02 for thoron, DCF is the factor used as 9 and 40nSv h^{-1}. Bq^{-1}.m^3 for radon and thoron respectively and OF is considered as 7000 h/y for both the gases, EF, DCF and OF gives their standard meaning.

2.2 RAD7

The RAD7 is a flexible, inclusive device being used to quantify instantaneously radon and thoron concentrations in the indoor and outdoor environment and its principle and operation details were given elsewhere. In the current study, RAD7 was used to examine diurnal fluctuations of indoor radon and thoron levels. The levels were measured in a dwelling of the study area for the entire day with one-hour interval.

3 Results and Discussion

The average concentration of radon and thoron estimated in the selected abodes of Peddamula village, Telangana over the year, by using passive technique is shown in Table 1. The estimated radon and thoron concentration is in the range of 14 -448Bq.m^{-3} with an average 120 ± 82 Bq.m^{-3}(GM: 100Bq.m^{-3}), and 7 -452 Bq.m^{-3}with an average of
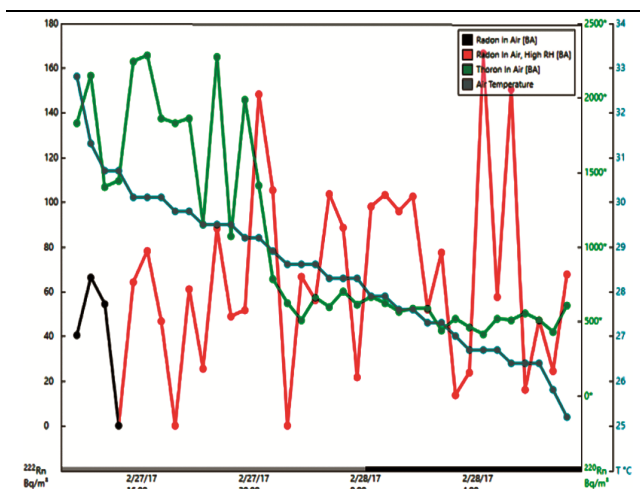
Fig. 2 — Diurnal measurement of radon and thoron.

Fig. 3 — The concentration of radon in seasons.

Table 1 — Computed average concentration (Bq. m^{-3}) of radon and thoron

location	radon		thoron	
L.No	range	Ave, ± SD	range	Ave. ± SD
P01	34 – 380	162 ± 133	16 – 215	113 ± 90
P02	31 – 180	119 ± 54	7 – 357	97 ± 146
P03	68 – 299	184 ± 163	23 – 169	96 ± 103
P04	37 – 111	81 ± 28	30 – 346	193 ± 119
P05	52 – 113	81 ± 31	80 – 106	96 ± 14
P06	53 – 154	102 ± 55	50 – 218	141 ± 84
P07	194 – 448	273 ± 120	30 – 332	210 ± 131
P08	69 – 134	100 ± 28	113 – 289	193 ± 73
P09	NA*	NA*	NA*	NA*
P10	91 – 111	101 ± 14	116 – 338	227 ± 157
P11	108 – 205	145 ± 52	123 – 198	173 ± 43
P12	14 – 108	61 ± 39	104 – 277	167 ± 78
P13	58 – 140	90 ± 42	68 – 452	164 ± 164
P14	80 – 112	99 ± 14	35 – 420	174 ± 174
P15	---	95	---	60
Total	14 – 448	120 ± 82	7 – 452	154 ± 111

*NA Unable to obtain the data due to poor response from the dweller

154 ± 111 Bq.m^{-3} (GM:112Bq.m^{-3}) respectively. It is revealed from the table (1), radon and thoron in the habitats of under the study region are moderately higher when compared with global averages of 40 Bq.m^{-3} for radon, and 10 Bq.m^{-3} for thoron respectively[4]. It is also be noted that, the large variability in the levels of radon and thoron in a small village is quite unexpected and this is attributed to varied structures of abodes, ventilation rates, and the life style of the habitants[8]. The calculated corresponding effective inhalation dose per year from the radon is found to vary from 0.35 to 11.2 with an average 3.02 mSv.y^{-1} and the same from the thoron is observed to vary between 0.24 and 12.6 with an average 4..32 mSv.y^{-1}.This is considerably higher than that of global average for radon and thoron 1.15mSv.y^{-1}, but it
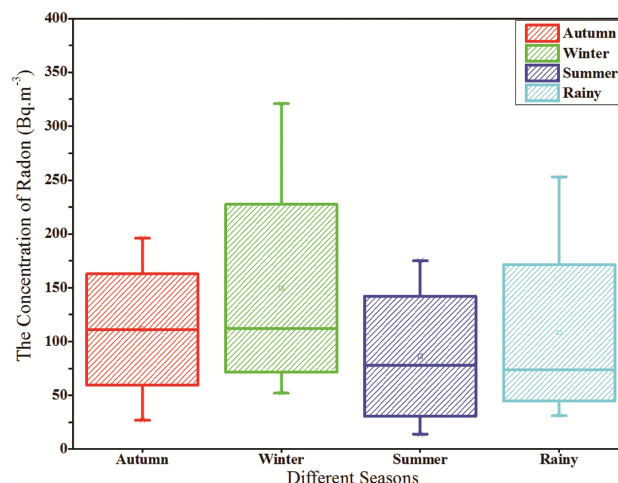
is within action limit (3 to 10 mSvy^{-1}) recommended by ICRP[3].

Diurnal measurements were carried out with RAD7 in a representative location for four seasons with an intension that to understand the change in the concentration of radon and thoron with time in the indoor environment. Though radon and thoron levels were recorded for all seasons, the generally distinct changeability is observed in the winter so that only the data recorded in the winter season is shown in Fig. 2. It elucidates that radon and thoron in the indoor environment show a transpose nature and this refer to the unconventional behaviour of thoron, and it is in line with earlier findings and this ascribed to its short half-life[9,10]. The variation of radon with time and temperature is consistent with earlier findings, and usually one can expect the radon levels are higher during dusk to dawn, since the reduced human activity result in accumulation of radon gas[11].

3.1 Seasonal variation: radon and thoron

An effort is made in this investigation to comprehend the seasonal change in radon and thoron levels in indoors, and is depicted in Fig. 3 & 4. One can be noticed that, radon and thoron concentration is predictable to be relatively higher during the winter spell is because of most of the residents are to be closed vents to conserve the heat energy and this enable the build-up of these gases in the indoors.

The radon and thoron levels were reasonably lower during summer, since dwellers have good ventilation and moreover the rise in temperature in the summer results in the dilution of gases. Whereas the thoron showing an unusual behaviour and is attributed to its short-life. The ratio of winter to autumn is 1.03, winter
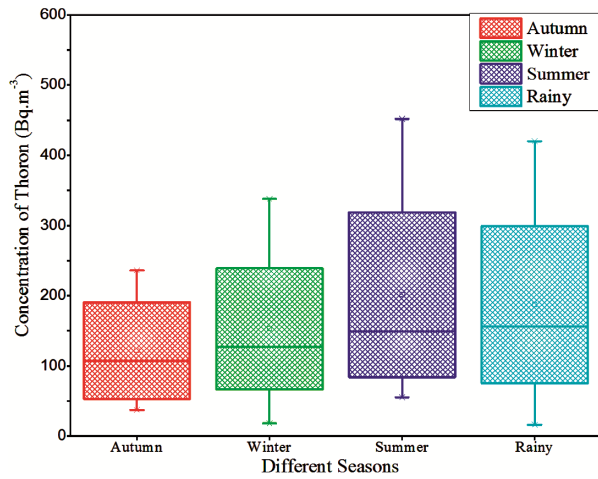
Fig. 4 — The concentration of thoron in seasons.

to summer is 1.23, and winter to rainy is 1.49 for radon in present study[12-15]. Likewise, for of thoron, the ratio of winter to summer is 0.75, winter to rainy is 0.78, and winter to autumn is 0.97. Similar trend is observed in different cases reported[12-19]. The unpredictability of thoron levels through seasons is dissimilar when compared to the radon because of inversion air movement of the thoron gas behaviour than other predictable gases[20].

3.2 The statistical distribution: radon and thoron

Statistically analysis of the data points is (from Fig. 5 & 6) conveying that, the concentration of radon and thoron in the houses under the investigation is followed lognormal distribution. It reveals that there
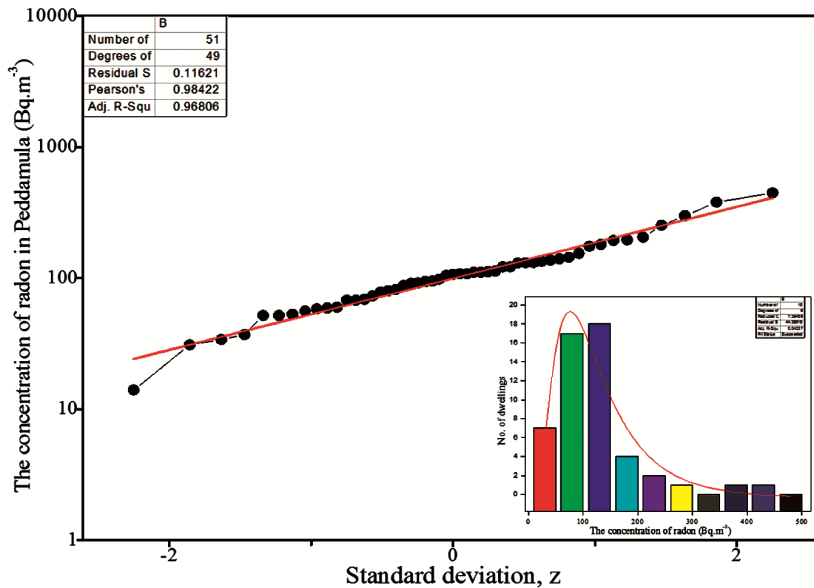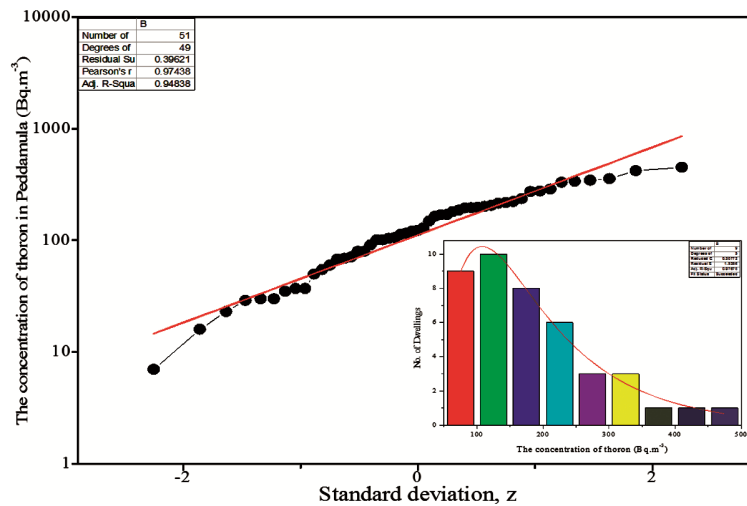

Fig. 5 — The statistical distribution of radon.

Fig. 6 — The statistical distribution of thoron.

is large variation among the estimated data points and gave a conjecture about the disproportionate weightage of the data points to the mean. This plots also described that the average radon and thoron levels in order, about 50% and 54% of the dwellings was recorded with in the action levels 100 – 300 Bq.m^{-3}, about 49% and 43% of dwelling was noted below 100 Bq m^{-3} and 1% and 3% of the dwellings were recorded exceeded the action level[3].

4 Conclusions

The concentration of ^{222}Rn and ^{220}Rngases under area of the study are widely varied and found to be three folds and fifteen folds more than that of the world averages of 40 Bq.m^{-3} and 10 Bq.m^{-3}, respectively. The diurnal and seasonal variation shows a unlike behaviour for radon and thoron, and but both exhibit a lognormal distribution and few dwellings were recorded the levels more than the prescribed action limit.

Acknowledgement

References

1   UNSCEAR ANNEX E, *United Nations Sci Comm Eff At Radiat 2006 Rep,* 2 (2006).
2   WHO, *World Health Organization,* ISBN 9789241547673, (2009).
3   ICRP, *ICRP Publication, Ann ICRP*, 115 (2010).
4   UNSCEAR, *Report to the General Assembly, with Scientific Annexes*, *UNSCEAR Rep*, (2000).
5   Rajaraman H S, Nagendra B G, Chavan S J, Achar K K & Ramesh B P V, *J Geol Soc India*, 82 (2013).
6   Verma M B, Maithani P B, Chaki A, Nageshwar Rao P & Kumar P,*Curr Sci,* 96 (2009) 4.
7   Sahoo B K, Sapra B K, Kanse S D, Gaware J J & Mayya Y S, *Radiat Meas*, 58 (2013).
8   Kumar A, Sharma S, Mehra R, Narang S & Mishra R, *Int J Occup Environ Health*, 23 (2017) 3.
9   Reddy K V K, Reddy M S, Reddy C G, Reddy P Y & Reddy K R, *J Radioanal Nucl Chem,* 292 (2012) 1092.
10 Suman G, Reddy K V K, Reddy M S, Reddy C G & Reddy P Y, *Sci Rep*, 11 (2021) 1.
11 Xie D, Liao M, Wang H & Kearfott K J, *Indoor Built Environ*, 26 (2017) 8.
12 Reddy M S, Reddy P Y, Reddy K R, Eappen K P, Ramachandran T V & Mayya Y S, *Radiat Prot Dosim*, 132 (2008) 4.
13 Reddy K V K, Reddy B S, Reddy M S, Reddy C G, Reddy P Y & Reddy K R*, Radiat Meas*, 36(2003)419.
14 Kamalakar D V, Vinutha P R, Kaliprasad C S & Narayana Y, *Environ Monitor Assess*, 194 (2022) 4.
15 Yashaswini T, Ningappa C, Subbaramu M C, Niranjan R S, Shashikumar T S & Suresh S, *J Radioanal Nucl Chem*, 326 (2020) 281.
16 Jamir S, Sahoo B K, Mishra R & Sinha D, *Radiat Prot Dosim*, 198 (2022) 12.
17 Gogoi P P & Barooah D, *Environ Monitor Assess*, 194 (2022) 12.
18 Rani S, Kansal S, Singla A K, Nazir S & Mehra R, *J Radioanal Nucl Chem*, 332 (2022) 1.
19 Sajwan R S, Joshi V, Kumar N, Dutt S, Rawat K, Prasad M & Ramola R C, *J Radioanal Nucl Chem*, 330 (2021) 3.
20 Reddy M S, Reddy P Y, Reddy C R & Eappen K P, *J Environ Radioact,* 73 (2004) 28.