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ASSESMENT OF RADON, THORON AND THEIR PROGENY CONCENTRATION AND ANNUAL INHALATION DOSE IN THE OUTDOOR EVIRONMENT AROUND KOLAR GOLD FIELDS OF KARNATAKA STATE, INDIA

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ABSTRACT

The concentration of outdoor radon (^{222}Rn), thoron (^{220}Rn) and their progeny around Kolar Gold Fields of Karnataka state, India were determined at 20 locations of the study area using single entry pinhole dosimeter and deposition progeny sensors. The outdoor radon and thoron concentration varies from 12.8±0.8 to 42.8±1.7 and 12.0±0.7 to 37.8±1.4 Bq.m^{-3} with an average value of 28.7±1.4 and 25.3±1.3 Bq.m^{-3}, respectively. Equilibrium Equivalent Concentration for radon and thoron values varies from 3.7±0.5 to 12.1±0.7and 0.6±0.2to 4.1±0.6 Bq.m^{-3} with an average value of 7.3±0.8 and 2.1±0.3 Bq.m^{-3}, respectively. The average values of equilibrium factor (EF) between radon, thoron and their progeny also calculated and found to be 0.24 and 0.07, respectively. The average annual total effective dose received due to radon, thoron and their progeny is 0.27 mSv.y^{-1} which is lesser than the global average value. The data obtained is compared with the world average values.

KEYWORDS:Radon, Thoron, EERC, EETC, Pinhole dosimeter, SSNTD.

INRODUCTION

Nearly 52% of radiation dose to mankind is attributed by inhalation of ^{222}Rn, ^{220}Rn and their progenies [1,2]. Radon and thoron are the naturally occurring radionuclides formed by the disintegration of their parents uranium and thorium present in building substances, distinct kinds of rocks and soils. The radon is taken into consideration as the second maximum essential reason for lung cancer in general public after smoking [2]. Hence it is very essential to monitor the activity level of these radionuclides in indoor environment. On the basis of epidemiological research in different nations, the WHO has insisted to reduce the radon action level from 200 to 100 Bq.m^{-3}[3].The major contributors to lung doses are radon and thoron progenies but not ^{222}Rn and ^{220}Rn.Therefore, it is very essential to estimate the progeniesdirectly [4].In this study, along with radon and thoron concentration, Equilibrium Equivalent Concentration of radon and thoron (EERC,EETC) and also seasonal variation has been estimated for the firsttime in this area.

GEOLOGY OF STUDY AREA

The present area of study is around Kolar Gold Fields (KGF) which almost covers the Kolar district in eastern most part of Karnataka State. It lies between 12º45´55.03″ and 13º36´42.05″ North latitudes and 77°50´25.06″ and 78°35´12.24″ East longitude. It is bounded on the north by Chikballapur district, on the east by Chittoor district of Andhra Pradesh State, on the south by Krishnagiri and Vellore district of Tamil Nadu State and on west by Bangalore rural district. Total area of the district is 3979 sq.km.

Kolar district is divided into sixtaluks namely, KGF,Bangarpet, Malur, Kolar, Mulbagal and Srinivaspura. Worlds second deepest underground mines (3209m) Bharath Gold Mine Limited (BGML) is located in this area. The key economic mineral deposit in the study area is gold. KGF is known to contain 26 number of gold bearing quartz lodes and bulk of the metal has come from the main champion quartz lode system having a strike length of 8 km and worked to a maximum vertical depth of about 3209 m.

Geologically, the study area belongs to hornblende gneiss, closepet granite, quartzite, champion gneiss, metabasalt, dolerite dyke and grey granite.Major portion of the study area consists of granite and hornblende gneiss. The different types of soil in study area are red sandy/loamy and lateritic soil. About 73% of the total area, is suitable for agriculture and horticulture; 3% for pasture andforestry and the remaining area is suitable for mining,quarrying and as habitat for wildlife.

Kolar district has eastern dry agro climate change. Bulk rainfall is received from south–west monsoon which sets in the month of May or June and continues upto the end of September. When the north east monsoon starts, Kolar district records very less average rainfall about 744mm to 800mm and hence, surface water sources are very less in number in the study area. The annual mean daily temperature is 34ºC maximum, and 15ºC minimum[5].Geological map of Kolar district with study locations is as shown in Fig. 1.

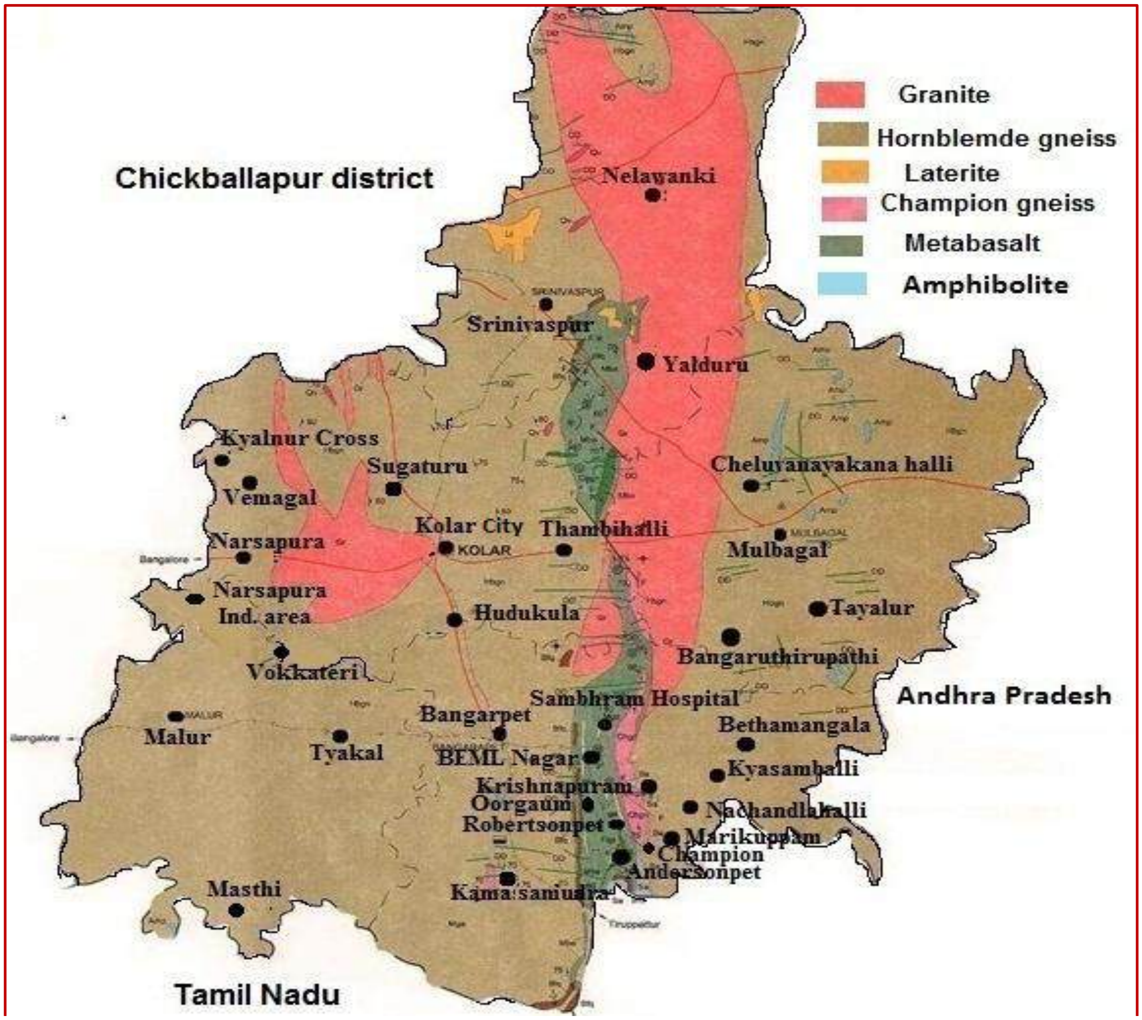

Fig. 1 Geological map of study area with study locations.

MATERIALS AND METHOD

In the present study, advanced and most accurate instrument for measurement of radon and thorn concentration in outdoor atmosphere is pin-hole dosimeter are used at 20 different locations around the study area.It has two identical cylindrical chambers of length 4.1 cm and radius 3.1 cm [6]. It has two compartments separated by a central pin-holes disc which acts as ^{222}Rn discriminator. The exposure of the detector inside the cup is termed as cup mode and the one exposed open is termed as the bare mode. The dosimeter has a single entry for the gas to the first chamber called 'radon+thoron' chamber through a glass fiber filter paper of thickness 0.56 μm and subsequently diffuses to the other cup is fully covered having four holes of 1mm diameter at the top to stop almost completely the entry of thoron gas to the second chamber known as 'radon chamber'. The Schematic diagram of Pin-hole dosimeter is shown in Fig 2.

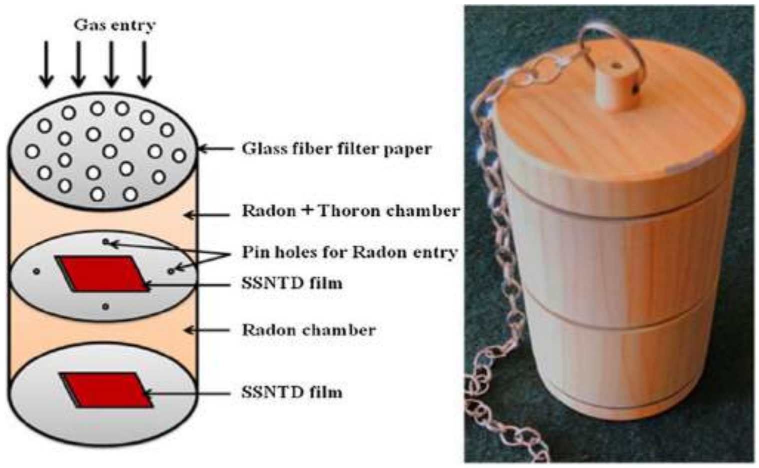

Fig. 2 Schematic diagram of pin-hole dosimeter.

The concentration of radon and thoron progeny is measured by using deposition based Direct Radon Progeny Sensors (DRPS) and Direct Thoron Progeny Sensors (DTPS) developed by the Baba Atomic Research Centre (BARC) [7]. These are made up of passive nuclear track detectors (LR-115 type II) mounted with absorbers of appropriate thickness. For thoron progeny, the absorber used is aluminized Mylar of 50 µm thickness which selectively detects only 8.78 MeV α- particles emitted from ^{212}Po. For radon progeny measurement, as absorber combination of aluminized Mylar of 25 µm thickness and a Cellulose Nitrate film of thickness 12 µm whose effective thickness of 37 µm is used which mainly detects α- particles emitted from ^{214}Po of its energy 7.69 MeV and ^{212}Po of its energy 8.78 MeV. This combination for absorber is made since 37 µm aluminized Mylar is not available in the market. The schematic diagram of this sensor (DTPS/DRPS) is shown in Fig. 3.

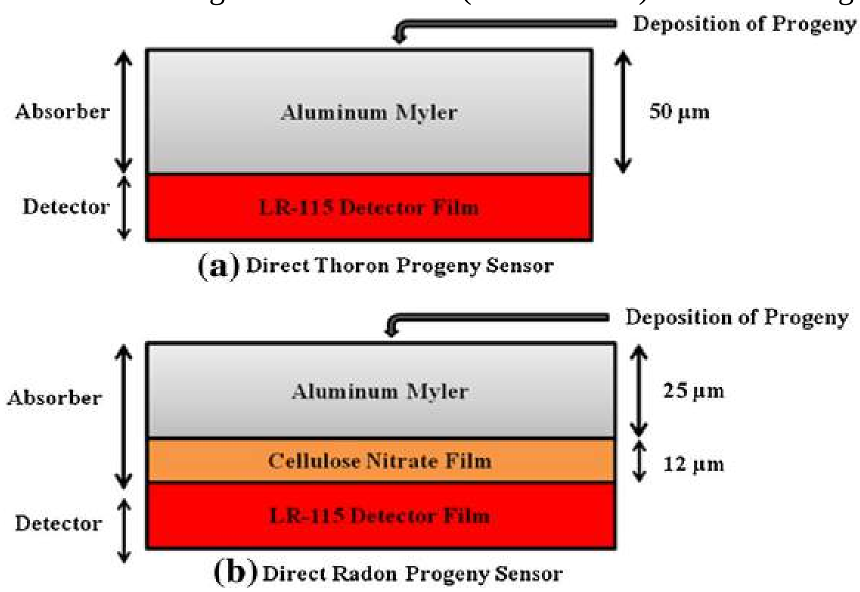

Fig. 3 Direct progeny sensor (DTPS/DRPS).

The dosimeters are suspended in the outdoor atmosphere at a height of 2.5 m from ground level. After the exposure period of 90 days in the atmosphere, the detector films are retrieved and chemically etched in 2.5NNaOH solution at 60^0 C for 60 min with mild agitation constant temperature bath. After the etching, the films were taken out from the etching vessel and washed in running tap water to remove alkali from surface and kept in distilled water for 1 h and then they were dried up in laboratory condition. Then the films were pealed out from the polymer surface. The tracks recorded on the films were then counted using spark counter (Model PSI-SC1) manufactured by Poll-tech Instruments Pvt. Ltd., Mumbai (India), which is an electronic counter operating at high voltage. The etched films were pre sparked at 900 V before counting. The spark counter was operated at operating voltage of 550 V while measuring. The recorded track densities are converted in to Bq.m^{-3} by using the calculated calibration factors.

Estimation of ^{222}Rn and ^{220}Rn concentration using single entry pin-hole dosimeter

The concentration of radon (^{222}Rn, C_R) and thoron (^{220}Rn, C_T) gases in outdoor environment is determined from the observed track densities in radon and 'radon+thoron' compartments by using the equations (1) and (2)[8].

$$C_R\ (\text{Bq.m}^{-3}) = \frac{T_1 - B}{D \times K_R} \text{------ (1)}$$

$$C_T(\text{Bq.m}^{-3}) = \frac{[T_2 - B] - T_1}{D \times K_T} \text{------ (2)}$$

where, 'T_1' and 'T_2' are the track densities registered in SSNTD films placed in radon and 'radon+thoron' compartments respectively, in pin-hole dosimeters, 'D' is the exposure period in days, 'B' is the background track density (4 Tracks.cm^{-2}), K_R= (0.017±0.002) Tracks.cm^{-2}/Bq.d.m^{-3}, K_T= (0.010±0.001) Tracks.cm^{-2}/Bq.d.m^{-3} are the calibration factors for radon compartment and thoron in 'radon+thoron' compartments, respectively.

Determination of Equilibrium Equivalent Radon Concentration (EERC) and Equilibrium Equivalent Thoron Concentration (EETC) using direct progeny sensors

The sensor which is used for the detection of thoron (^{222}Rn) progeny is known as Direct Thoron Progeny Sensor (DTPS) and the sensor which is used for radon (^{220}Rn) progeny is known as Direct Radon Progeny Sensor (DRPS). The basic principle of operation of these sensors is that the LR-115 detector detects the alpha particles emitted from the deposited progeny atoms. In calculating the progeny concentrations, the track density obtained using DTPS is used directly to calculate the Equilibrium Equivalent Thoron Concentration (EETC), since comparatively larger thickness (50 µm) of the absorber used in DTPS which does not allow radon progeny to pass through it. Hence there is no interference of radon progeny to thoron progeny in this section. In case of Equilibrium Equivalent Radon Concentration (EERC), since α energy of ^{212}Po (thoron progeny) is higher than that of ^{214}Po (radon progeny), the alpha particles emitted from both radon progeny and thoron progeny pass through the absorber (37 µm) used in the DRPS and hence to calculate EERC, the tracks produced by the thoron progeny are eliminated as calculated from DTPS. The Equilibrium Equivalent Thoron Concentration (EETC) is calculated using the equation (3)[9].

$$\text{EETC} = \frac{T_1 - B}{D \times S_T} \text{------ (3)}$$

Where 'T_1' is the track densities recorded on DTPS, 'D' is the exposure period in days, 'B' is the background counts and S_T =(0.94±0.027) Tracks.cm^{-2}.d^{-1}/EETC (Bq.m^{-3}) is the sensitivity factor for thoron progeny [10].

The Equilibrium Equivalent Radon Concentration (EERC) is calculated from exact track density from radon progeny in DRPS obtained from equation (4)[11]

$$T_{Rn} = T_{DRPS} - \frac{\eta_{RT}}{\eta_{TT}} T_{DTPS} \text{ ------ (4)}$$

where, η_{RT} = (0.01±0.0004) is the track registration efficiency for thoron progeny in DRPS and η_{TT} =

(0.083±0.0004) is the track registration efficiency for thoron progeny in DTPS, respectively.

The EERC is calculated using the equation (5)[9].

$$EERC = \frac{T_{Rn} - B}{D \times S_R} \text{------ (5)}$$

Where, S_R = (0.09±0.0004) Tracks.cm^{-2}.d^{-1}/EERC (Bq.m^{-3}) is the sensitivity factor for radon progeny [10].

Estimation of Equilibrium Factors for radon and thoron

The Equilibrium Factor (EF) is the measure of the degree ofradioactive equilibrium between radon, thoron and its short-lived radioactive decay products. This is calculated by the ratio of their progeny concentration to their concentration for individual dwellings and is given by the equation (6) and (7)[6].

$$\text{Equilibrium Factor for Radon} = \frac{EERC}{\text{Radon concentration}} \text{------ (6)}$$

$$\text{Equilibrium Factor for Thoron} = \frac{EETC}{\text{Thoron concentration}} \text{------ (7)}$$

Calculation of annual inhalation dose

From radon, thoron and their progeny concentration values, outdoor inhalation dose is calculated by using conversion coefficient 9 nSv for radon and 40 nSv for thoron from using the equation (8),[11].

$$D_{out}(mSv.y^{-1}) = \{(0.17 \times C_R + 9 \times EERC) + (0.11 \times C_T + 40 \times EETC)\} \times 8760 \times 0.2 \times 10^{-6} \text{ ---(8)}$$

Where, $D_{out}$is the outdoor inhalation dose and C_R & C_T are the radon and thoron concentration, respectively.

RESULTS AND DISCUSSION

Concentration of radon, thoron and their progeny

The concentration of radon and thoron in outdoor measured using advanced pinhole dosimeters based on SSNTDs (LR-115, Type II), and their corresponding progeny using deposition based direct progeny sensors (DRPS and DTPS) and the obtained values are summarized in Table 1.

The concentration of radon and thoron in outdoor atmosphere varies from 12.8±0.8 to 42.8±1.7 Bq.m^{-3} and 12.0±0.7 to 37.8±1.4 Bq.m^{-3} with an average value 28.7±1.4 Bq.m^{-3} and 25.3±1.3 Bq.m^{-3}, respectively higher than the world average values of 40 and 3 Bq.m^{-3} [12].

The locations selected for outdoor study are randomly chosen at different places of the study area. It is observed that the large variation of radon and thoron concentration from one place to another and average radon concentration is higher than thoron concentration. In some places, thoron concentration is higher than the radon concentration. This is due to various factors like variation in activity of radium and thorium in soil, rocks, building materials used for construction of houses, ventilation condition, radon in water, local geology and meteorological parameters etc., [13].

The outdoor Equilibrium Equivalent Radon Concentration (EERC) and Equilibrium Equivalent Thoron Concentration (EETC) are measured using Direct Radon Progeny Sensors (DRPS) and Direct Thoron Progeny Sensors (DTPS) respectively. The outdoor EERC and EETC values vary from 3.7±0.5 to 12.1±1.0 Bq.m^{-3} and 0.6±0.2 to 4.1±0.6 Bq.m^{-3} with an average value of 7.3±0.8 Bq.m^{-3} and 2.1±0.3 Bq.m^{-3}, respectively. The EERC value is more than the EETC which is due to the fact that the outdoor EERC and EETC mainly depends on the

^{222}Rn and ^{220}Rn exhalation from materials like rocks, soil and minerals present in nature.

The higher values of outdoor radon, thoron and their progeny concentration are observed in Nelawanki, Yalduru, Kolar city and Srinivaspura. This is due to these places consisting granitic rocks exposing outer surface of the earth which has higher activity of radionuclides [14-16,].

The higher values of outdoor radon, thoron and their progeny concentration are observed at the places having granitic rocks which have higher activity of radionuclides. It also depends on type of building materials, ventilation condition and local geology. At the places having Metabasalt and Metagabbro rocks and good ventilation condition of all the dwellings, lower concentration of radon, thoron and their progeny levels is observed.

The seasonal variation of outdoor average radon, thoron and their progeny concentration is shown in Fig. 4 to Fig. 5, respectively. The results show that the higher concentration of radon, thoron and their progeny and annual inhalation dose are observed during winter season when compared to summer and rainy seasons. Since in winter season water content in air is more, the radon, thoron and their progeny remain trapped by water vapour, and are more difficult to remove than free gases because they are highly soluble in water [17].

Slightly lesser values of radon, thoron and their progeny concentration and annual inhalation dose outdoor are observed during rainy season compared to winter season. The soil in this season becomes saturated with water which means soil pores get filled by water, and hence less concentration is exhaled resulting in lower concentration [18, 19].

Lower values of radon, thoron and their progeny concentration and annual inhalation dose in outdoor are observed during summer season when compared to winter and rainy season. In summer, the higher rate of vertical mixing and dispersions lift the aerosols to higher altitudes resulting in decrease in the concentration near the ground level air [20].

Table: 1 Average outdoor radon, thoron and their progeny concentration and inhalation dose in and around Kolar Gold Fields.

Sl. No.	Place	Concentration (Bq.m^{-3})		Progeny conc. (Bq.m^{-3})		Equilibrium factor		Inhalation dose (mSv.y^{-1})
		^{222}Rn	^{220}Rn	EERC	EETC	^{222}Rn	^{220}Rn	
KGF Taluk								
01	Robertson Pet	14.2±1.1	15.4±0.9	3.8±0.6	0.7±0.3	0.27	0.05	0.12
02	Marikuppam	12.8±0.8	12.0±0.7	3.7±0.9	0.6±0.2	0.29	0.05	0.11
03	Sambhram Hospital	14.4±0.9	12.6±0.8	3.7±0.5	0.8±0.4	0.26	0.06	0.12
04	Bethamangala	27.6±1.3	24.4±1.1	5.0±1.1	1.0±0.3	0.17	0.04	0.16
BangarpetTaluk								
05	Bangarpet	19.6±1.4	20.9±1.0	5.1±0.9	1.0±0.3	0.25	0.05	0.16
06	Kamasamudra	18.4±1.5	16.7±1.1	4.6±0.8	0.9±0.2	0.24	0.05	0.14
07	Hudukula	22.0±1.7	19.9±1.2	5.3±1.0	0.8±0.2	0.23	0.04	0.15
MalurTaluk								
08	Tyakal	29.4±1.5	26.4±1.8	5.9±0.9	1.4±0.4	0.19	0.05	0.20
09	Malur	33.6±1.8	31.0±1.5	6.8±1.0	1.8±0.3	0.19	0.06	0.25
10	Masthi	25.7±1.4	23.4±1.2	8.3±0.8	2.4±0.5	0.29	0.1	0.31
Kolar Taluk								

11	Vokkaleri	28.7±0.9	22.2±1.4	7.5±0.8	2.6±0.4	0.25	0.11	0.31
12	Vemagal	24.3±0.7	25.3±1.2	6.8±0.7	2.2±0.3	0.25	0.08	0.28
13	Kolar City	39.5±1.6	33.4±1.5	10.0±1.1	2.7±0.4	0.23	0.08	0.36
14	Thambihalli	36.8±1.4	31.0±1.7	9.1±0.8	2.6±0.2	0.23	0.08	0.34
MulbagalTaluk								
15	Bangaruthirupathi	34.1±1.3	27.2±1.1	8.7±0.6	2.8±0.1	0.24	0.1	0.35
16	Tayalur	31.3±1.4	23.9±1.3	7.7±0.5	2.5±0.3	0.23	0.1	0.31
17	Mulbagal	36.5±1.9	30.5±1.7	8.5±0.7	3.0±0.2	0.21	0.09	0.36
SrinivaspuraTaluk								
18	Srinivaspura	40.7±2.0	34.0±1.2	11.7±1.0	3.7±0.4	0.27	0.11	0.46
19	Yalduru	42.8±1.7	37.8±1.4	11.1±1.1	3.8±0.5	0.24	0.1	0.46
20	Nelawanki	42.5±1.5	37.1±1.8	12.1±1.0	4.1±0.6	0.27	0.11	0.50
Minimum		12.8±0.8	12.0±0.7	3.7±0.5	0.6±0.2	0.17	0.04	0.11
Maximum		42.8±1.7	37.8±1.4	12.1±1.0	4.1±0.6	0.29	0.11	0.50
Average		28.7±1.4	25.3±1.3	7.3±0.8	2.1±0.3	0.24	0.07	0.27

EERC - *Equilibrium Equivalent Radon Conc.,*

EETC- *Equilibrium Equivalent Thoron Conc.*

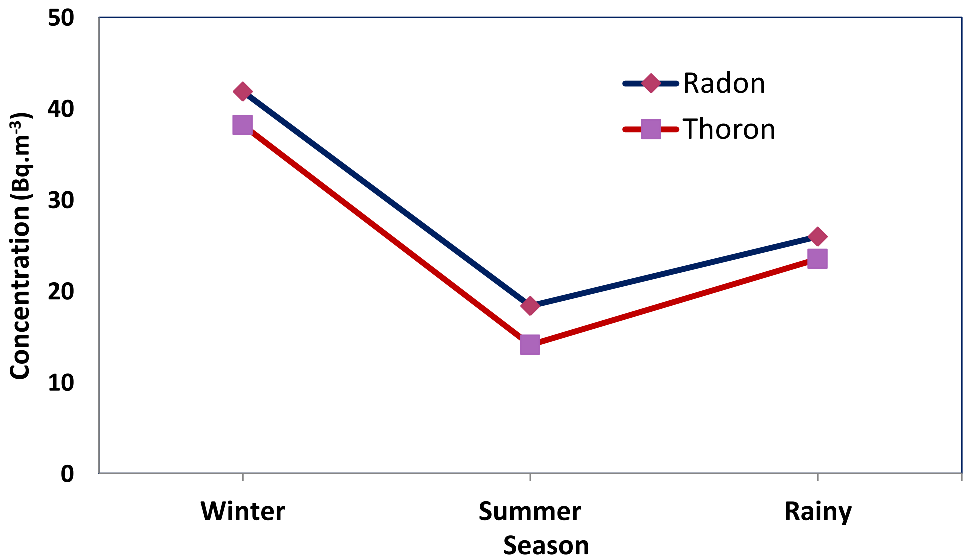

Fig. 4 Seasonal variation of average concentration of outdoor radon and thoron.

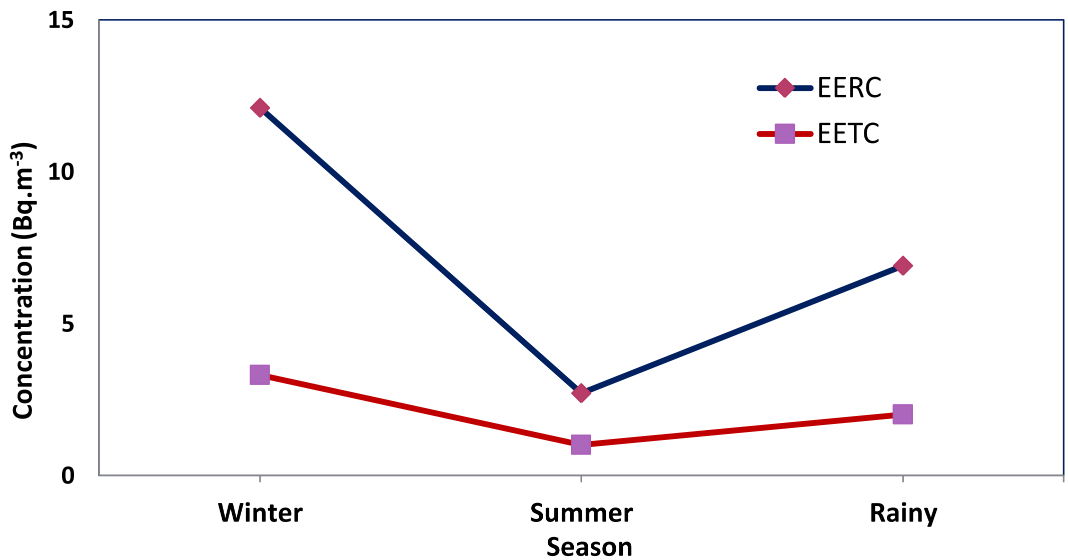

Fig. 5 Seasonal variation of average outdoor radon and thoron progeny concentration.

Equilibrium factors for radon and thoron

The Equilibrium Factor (EF) is the measure of the degree of radioactive equilibrium between radon, thoron, and its short-lived radioactive decay products, and is important to determine the dose accurately. The estimated values of average outdoor equilibrium factors for radon and thoron are summarized in the Table 1. The average outdoor radon and thoron equilibrium factor varies from 0.17 to 0.29 and 0.04 to 0.11 with an average value of 0.24 and 0.07, respectively. The average value of radon in outdoor environments is lesser than the UNSCEAR reported values of 0.4 for radon [2] and higher than the reported value of 0.03 for thoron [21-24].

Annual inhalation dose

The inhalation dose of radon, thoron and their progeny is determined by using the equilibrium factor for radon and thoron at each place and is summarized in Table 1. From the obtained data, it has been observed that the outdoor annual inhalation dose varies from 0.11 to 0.50 $mSv.y^{-1}$ with an average value of 0.27 $mSv.y^{-1}$. At all the places, obtained values are within the action level of 3-10 $mSv.y^{-1}$ as recommended by ICRP [25].

CONCLUSION

The concentration of radon, thoron and their progeny is measured in outdoor environment at 20 different places around study area using pin-hole dosimeters in summer, winter and rainy seasons. The average outdoor concentration of radon value in the present study is 28.7 $Bq.m^{-3}$ and for thoron is $Bq.m^{-3}$ which is lower than the world average value of 40 $Bq.m^{-3}$ for dwellings and national average of 42 $Bq.m^{-3}$ recommended by UNSCEAR 2000, and lower than the action level of 100 $Bq.m^{-3}$ recommended by WHO and the average thoron concentration value is 25.3 $Bq.m^{-3}$ which is higher than the world average value of 10 $Bq.m^{-3}$ for dwellings and national average of 12.2 $Bq.m^{-3}$ recommended by UNSCEAR 2000.

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