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SEASONAL VARIATION OF RADON, THORON AND THEIR PROGENY IN THE INDOOR ENVIRONMENT OF GOGI REGION

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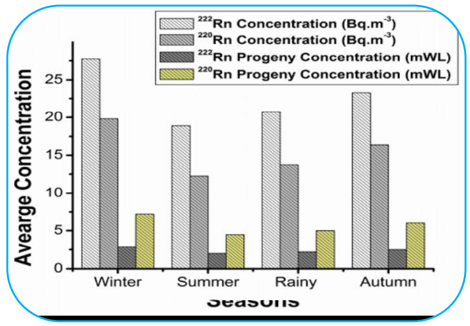
ABSTRACT:
Inhalation of radon (^{222}Rn), thoron (^{220}Rn) and their progenies are the major sources of natural radiation exposure. Keeping this in view, seasonal indoor radon measurement studies have been carried out in 100 dwellings of Gogi region of Yadgir District, Karnataka, India. LR-115 Type II films were exposed for four seasons of 3 months each covering a period of 1 year for the measurement of indoor radon and thoron levels using the pinholes dosimeter and Direct Radon/Thoron Progeny Sensors. The mean annual estimated inhalation dose received by the residents of the studied area was estimated to be 1.2 mSv.



KEYWORDS: *radon, thoron, progeny, dosimeter, LR-115 film.*

1.INTRODUCTION

We live in a naturally radioactive world and are constantly being exposed to natural radiation from the surrounding environment. Mainly, natural radiations originating from the soils and rocks of the subjacent earth are the major contributor to the total dose received by the mankind; among them, the primordial radionuclides such as ^{40}K, ^{238}U and ^{232}Th are of more significance. The radon and thoron concentration is highly inhomogeneous and is strongly dependent on the distance from the source (Zubair et al., 2011). The present study focuses on radon (^{222}Rn), thoron (^{220}Rn) and their progeny measurements because they contribute more than 50% of the natural background radiation dose originated from the ^{238}U and ^{232}Th radionuclides respectively (UNSCEAR, 2000; El-Zaher et al., 2011). Radon is the natural radioactive gas occurs ubiquitously throughout the world. It is the decay product of ^{226}Ra, has a half-life of 3.82 days ^{220}Rn is an isotope of radon which has a half-life of 55.6 seconds (Vanchhawng et al., a thesis report, 2012). In the present study, the radon, thoron, and their progeny measurements were carried out in the indoor dwellings of Gogi region, Yadgir district, Karnataka, India covering the 5 km range from the proposed Uranium mining area of Uranium Corporation of India Limited (UCIL). A total of six villages were covered to assess the inhalation dose due to Radon, Thoron, and their progeny.

The investigation region belongs to Yadgir district lies in the northern part of Karnataka between 16° 11'- 16° 50' N Latitudes and 76° 17' - 77° 28' E Longitudes, with a geological region of 5234.4 Sq.km. The northern part of the district represents a plateau region, typically of Deccan Trap territory and is deeply indented with gorges. Soil types in the area are profound dark, medium dark soil, shallow soil, and lateritic soil. Profound & medium dark soil covers practically the entire study area, with the exception of a little segment towards the northern part of the study region whereas a lateritic soil occurs in small extent towards the northern part of the region (Groundwater board Yadgir, 2012). The data obtained in the present study with pinholes based dosimeter deployed side by side with direct radon progeny sensor (DRPS) and direct thoron progeny sensor (DTPS) badges will provide the future specialists a gauge information for correlation and further ecological radioactivity research of the study region.

2. MATERIALS AND METHODS:

The radon, thoron and their progeny measurements were carried out in the indoor dwellings of Gogi region, Yadgir district, Karnataka, India. In this region, Gogi (K), Gogi Peth, Singanahalli, Karkalli, Rabanalli, and Kanchinakavi villages were covered and a total of 32, 30, 09, 10, 15 and 4 dwellings were selected respectively. The map showing the villages covered in the Gogi region is shown in Fig. 1. The importance of the study is that this region is within 5 km radius from the proposed Uranium mining area. The different types of dwellings were selected for the deployment of the dosimeters such as Reinforced Concrete Construction (RCC), Rock + Wood, Mud, Tin, and RCC + Wood ceilings. The Radon and thoron measurements were carried out using LR-115 plastic track detector (Solid State Nuclear Track Detectors) exposed in the radon-thoron environment in a well-designed pinholes dosimeter, which is known radon and thoron discriminating dosimeter (Sahoo et al., 2013). The pin holes based dosimeter has a single entry for both radon and thoron gases separated by two chambers The Solid State Nuclear Track Detector (SSNTD) LR-115 cellulose nitrate film was used as a detector, which has the advantage to be mostly unaffected by humidity, low temperatures, moderate warming and light (Mehra et al., 2013). Each chamber contains an LR-115 film, where a first chamber is a radon + thoron chamber which detects both radon and thoron, while the second chamber detects the alpha emission due to radon gas only.

For measuring radon and thoron progeny concentrations, the Direct Radon/Thoron Progeny Sensors (DRPS/DTPS) were used (Mishra and Mayya 2008, Mishra et al., 2009). It is a deposition based alpha track registration technique, wherein the tracks are created due to deposited progeny atoms on the detector surface. The detector has two components, an energy degrader Aluminized foil, which provides a selective registration of emitted alpha particles; and an LR115 film which registers the alpha particle which has sufficient energy to cross the energy degrader and reach the film. Based on the thickness of the energy degrader Aluminized mylar film, two detectors were used called as DTPS (Direct Thoron Progeny sensor) and DRPS (Direct Radon Progeny sensor) badges (Mishra et al., 2014). Wire-mesh capped DRPS/DTPS (Mishra et al., 2010) was used along with the bare DTPS/DRPS to measure the attached fraction of progeny concentration. Four sets of deployments were carried out in each house for three months (90 days) each from January 2013-January 2014. A total of 100 houses were covered, which consists of different house types as shown in Fig. 1. Pinhole dosimeter, DTPS/DRPS in bare mode and wire-mesh capped mode were deployed simultaneously in each house, 20 cm away from the wall.

After the exposure for 3 months, all the detectors were retrieved and analyzed. The films were etched using a 2.5 N NaOH solution at 60°C for 90 min without stirring [Avinash et al., 2014]. Subsequently, the tracks were counted using a spark counter and these counted tracks are converted into the radionuclide concentrations by the use of appropriate calibration factors. For the pinholes dosimeters, the calibration factor for the radon+thoron chamber was used as 0.010 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ and that for only radon chamber was 0.017 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ [Sahoo et al., 2013]. For DTPS, the calibration factor used was 0.94 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ [Mishra et al., 2008] and for DRPS was 0.09 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ [Mishra et al., 2014, Vanchhawng et al., 2011]. For wire-mesh capped DTPS and the DRPS the calibration factors were 0.33 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ and 0.04 (Track cm^{-2} d^{-1}) (Bq m^{-3})$^{-1}$ respectively [Mayya et al., 2010]. The annual inhalation dose of the present study region is calculated using the following relation

$$A_{ID} = (C_{Rn} \times 0.17 + C_{Tn} \times 0.11 + EEC_{Rn} \times 9 + EEC_{Tn} \times 40) \times 8760 \times 0.8 \times 10^{-6}\ mSv$$

where C_{Rn} and C_{Tn} are the concentration of radon and thoron in Bq m^{-3}, EEC_{Rn} and EEC_{Tn} are the respective radon and thoron progeny concentrations. 0.17 and 0.11 nSv (Bqh $m^{-3})^{-1}$ are the dose conversion factors for radon and thoron gas, 9 and 40 nSv (Bqh $m^{-3})^{-1}$ are the dose conversion factors for radon and thoron progenies [Avinash et al., 2014; Mukesh et al., 2014], 8760 h/y is the indoor occupancy time, 0.8 is the Indoor occupancy factor.

RESULTS AND DISCUSSION:

2.1 Radon and thoron gas distribution in the indoor environment:

^{222}Rn and ^{220}Rn gas concentrations were measured using the pinholes dosimeter. These values inside the dwellings varied quite significantly and a wide range of variations was found in the concentrations of radon and thoron gases. Table 1 gives the statistics of the ^{222}Rn and ^{220}Rn concentrations in Bq m^{-3} for all the samples throughout the year 2013-14. In Jan-Apr (spring) season, the ^{222}Rn concentration varies from 24.2 to 54.8 Bq m^{-3} with a GM of 37.0 Bq m^{-3}. In Apr-Jul (summer) season, the ^{222}Rn concentration varies from 19.6 to 53.6 Bq m^{-3} with a GM of 32.5 Bq m^{-3}. In Jul-Oct (rainy) season, the ^{222}Rn concentration varies from 20.3 to 53.6 Bq m^{-3} with a GM of 34.4 Bq m^{-3}. In Oct-Jan (winter) season, the ^{222}Rn concentration varies from 37.9 to 97.4 Bq m^{-3} with a GM of 58.5 Bq m^{-3}.
On the other hand, ^{220}Rn concentration in Jan-Apr (spring) season, the varied from 21.1 to 55.6 Bq m^{-3} with a GM of 32.6 Bq m^{-3}. In Apr-Jul (summer) season, the ^{220}Rn concentration varied from 16.7 to 50.0 Bq m^{-3} with a GM of 27.7 Bq m^{-3}. In Jul-Oct (rainy) season, the ^{220}Rn concentration varied from 17.8 to 50.0 Bq m^{-3} with a GM of 29.1 Bq m^{-3}. In Oct-Jan (winter) season, the ^{220}Rn concentration varied from 34.4 to 83.3 Bq m^{-3} with a GM of 54.0 Bq m^{-3}.

2.2 Radon and thoron progeny distribution in the indoor environment

^{222}Rn and ^{220}Rn progeny concentrations were measured using the deposition based DTPS-DRPS badges. These values inside the dwellings varied quite significantly and a wide range of variations was found especially in the concentrations of thoron progenies. Table 2 gives statistics of ^{222}Rn and ^{220}Rn progeny concentrations measured in dwellings around Gogi region. In Jan-Apr (spring) season, the ^{222}Rn progeny concentration varied from 8.9 to 20.0 Bq m^{-3} with a GM of 12.1 Bq m^{-3}. In Apr-Jul (summer) season, the ^{222}Rn progeny concentration varied from 6.9 to 20.5 Bq m^{-3} with a GM of 10.5 Bq m^{-3}. In Jul-Oct (rainy) season, the ^{222}Rn progeny concentration varied from 7.2 to 19.1 Bq m^{-3} with a GM of 11.7 Bq m^{-3}. In Oct-Jan (winter) season, the ^{222}Rn progeny concentration varied from 12.2 to 29.8 Bq m^{-3} with a GM of 18.3 Bq m^{-3}.

Subsequently, the ^{220}Rn progeny concentration of the Gogi region is determined. In Jan-Apr (spring) season, the ^{220}Rn progeny concentration varied from 0.60 to 1.96 Bq m^{-3} with a GM of 1.07 Bq m^{-3}. In Apr-Jul (summer) season, the ^{220}Rn progeny concentration varied from 0.54 to 1.95 Bq m^{-3} with a GM of 0.94 Bq m^{-3}. In Jul-Oct (rainy) season, the ^{220}Rn progeny concentration varied from 0.67 to 1.94 Bq m^{-3} with a GM of 1.09 Bq m^{-3}. In Oct-Jan (winter) season, the ^{220}Rn progeny concentration varied from 1.16 to 2.48 Bq m^{-3} with a GM of 1.64 Bq m^{-3}.

2.3 Attached radon and thoron progeny distribution in the indoor environment

The attached fraction of ^{222}Rn and ^{220}Rn progeny concentrations were measured using the Wire-mesh capped DTPS-DRPS badges. These values inside the dwellings found to be very close to the total progeny concentration. This indicates very low unattached fraction. Table 3 gives statistics of all the values of attached ^{222}Rn progeny concentration measured in dwellings around Gogi region. In Jan-Apr (spring) season, the attached ^{222}Rn progeny concentration varied from 8.2 to 19.2 Bq m^{-3} with a GM of 11.6 Bq m^{-3}. In Apr-Jul (summer) season, the attached ^{222}Rn progeny concentration varied from 6.4 to 20.4 Bq m^{-3} with a GM of 10.1 Bq m^{-3}. In Jul-Oct (rainy) season, the attached ^{222}Rn progeny concentration varied from 6.9 to 18.5 Bq m^{-3} with a GM of 11.2 Bq m^{-3}. In Oct-Jan (winter) season, the ^{222}Rn progeny concentration varied from 11.2 to 26.5 Bq m^{-3} with a GM of 17.1 Bq m^{-3}.

Subsequently, the attached ^{220}Rn progeny concentrations of the Gogi region were also measured. In Jan-Apr (spring) season, the attached ^{220}Rn progeny concentration varied from 0.54 to 1.86 Bq m^{-3} with a GM of 1.06 Bq m^{-3}. In Apr-Jul (summer) season, the attached ^{220}Rn progeny concentration varied from 0.51 to 1.92 Bq m^{-3} with a GM of 0.95 Bq m^{-3}. In Jul-Oct (rainy) season, the attached ^{220}Rn progeny concentration varied from 0.55 to 1.88 Bq m^{-3} with a GM of 1.08 Bq m^{-3}. In Oct-Jan (winter) season, the ^{220}Rn progeny concentration varied from 1.04 to 2.19 Bq m^{-3} with a GM of 1.55 Bq m^{-3}.

The annual inhalation dose was also measured in the indoor environment of the study area, see Table 4. It shows that the dose found to be higher in the winter season of about 2.8 $mSvy^{-1}$ and a lower in the summer season of about 1 $mSvy^{-1}$. The overall mean annual inhalation dose in the present study was found to be 1.2 $mSvy^{-1}$, which is within the permissible limits of the UNSCEAR 2000 report.

The test distribution normality with the moment coefficients for radon and thoron is estimated by using a statistics known as skewness and kurtosis to express how the shapes of sample frequency distribution curves differ from ideal Gaussian (normal). Both positive and negative skew was observed in all the seasons for radon, thoron and their progeny, showing an asymmetric distribution. The distribution of radon, thoron, and progeny was also found to be sharp with both positive and negative kurtosis values in all the seasons (Kakali et al., 2010).

In the present study, the radon concentration was found higher than thoron concentration, but the thoron concentration was also found to be higher as radon concentration throughout the year (Table. 4). The Fig. 2 shows the radon and thoron concentrations found seasonally for the different type of houses. As shown in the figure, there was no significant difference in radon or thoron concentration versus the type of houses. In all the house types, higher radon and thoron concentrations were observed in a winter season.

3 CONCLUSIONS

The seasonal variation of a set of the simultaneous long-term mean radon, thoron and progeny concentration measurements were carried out in around 100 dwellings of Gogi region during the year 2013-14. The radon concentrations were observed to be higher compared with the thoron gas concentrations. The progeny concentrations were found to be in the same range throughout the year. The attached fraction of the progeny concentration was also found to be very close to the total progeny concentrations (Table 3). This indicates very low unattached fraction. The overall mean annual inhalation dose in the present study region is found to be 1.2 mSv. This shows that the data measured in the present region are in good agreement with the literature results. Statistical observations show that radon, thoron and their progeny concentrations in houses of the study area exhibit an asymmetric distribution with a long asymmetric tail either on the right or left of the median. No significant difference in radon and thoron gas concentrations was observed in different house types. However, an increase in radon and thoron concentrations in winter season was measured in all types of houses.

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Table 1. Distribution of radon and thoron gas concentration levels of Gogi region.

Statistics	Radon concentration in Bq m^{-3}				Thoron concentration in Bq m^{-3}			
	Spring	Summer	Rainy	Winter	Spring	Summer	Rainy	Winter
Minimum	24.2	19.6	20.3	37.9	21.1	16.7	17.8	34.4
Maximum	58.8	53.6	53.6	97.4	55.6	50.0	50.0	83.3
GM	37.0	32.5	34.4	58.5	32.6	27.7	29.1	54.0
SD	8.5	8.2	8.4	12.3	8.2	8.2	8.4	10.8
GSD	1.54	1.61	1.60	1.47	1.60	1.73	1.72	1.46
Skewness	0.65	0.59	0.46	1.06	0.70	0.70	0.55	0.66
Kurtosis	-0.27	-0.43	-0.87	0.72	-0.13	-0.29	-0.72	-0.26

Table 2. Distribution of radon and thoron progeny concentration levels of Gogi region.

Statistics	Radon progeny concentration in Bq m^{-3}				Thoron progeny concentration in Bq m^{-3}			
	Spring	Summer	Rainy	Winter	Spring	Summer	Rainy	Winter
Minimum	8.9	6.9	7.2	12.2	0.60	0.54	0.67	1.16
Maximum	20.0	20.5	19.1	29.8	1.96	1.95	1.94	2.48
GM	12.1	10.5	11.7	18.3	1.07	0.94	1.09	1.64
SD	2.9	3.1	3.0	3.8	0.33	0.36	0.33	0.29
GSD	1.53	1.69	1.60	1.48	1.74	1.92	1.74	1.41

Skewness	1.17	1.10	0.93	0.85	0.94	1.12	0.68	0.58
Kurtosis	0.61	0.28	-0.28	0.42	0.01	0.14	-0.62	-0.36

Table 3. Distribution of attached radon and thoron gas concentration levels of Gogi region.

Statistics	Attached Radon progeny concentration in Bq m^{-3}				Attached Thoron progeny concentration in Bq m^{-3}			
	Spring	Summer	Rainy	Winter	Spring	Summer	Rainy	Winter
Minimum	8.2	6.4	6.9	11.2	0.54	0.51	0.55	1.04
Maximum	19.2	20.4	18.5	26.5	1.86	1.92	1.88	2.19
GM	11.6	10.1	11.2	17.1	1.06	0.95	1.08	1.55
SD	2.8	3.1	3.0	3.6	0.31	0.35	0.33	0.28
GSD	1.54	1.71	1.62	1.49	1.74	1.93	1.80	1.43
Skewness	1.14	1.12	0.96	0.62	0.93	1.10	0.70	0.54
Kurtosis	0.53	0.40	-0.22	-0.21	-0.02	0.12	-0.50	-0.62

Table 4. Distribution of the mean annual inhalation dose levels of Gogi region.

Statistics	Annual inhalation dose (mSvy^{-1})			
	Spring	Summer	Rainy	Winter
Minimum	0.8	0.6	0.7	1.2
Maximum	1.9	1.8	1.8	2.8
GM	1.1	1.0	1.1	1.7
SD	0.3	0.3	0.3	0.3
GSD	1.58	1.73	1.63	1.45
Skewness	1.07	1.29	0.80	0.78
Kurtosis	0.25	0.74	-0.50	0.27

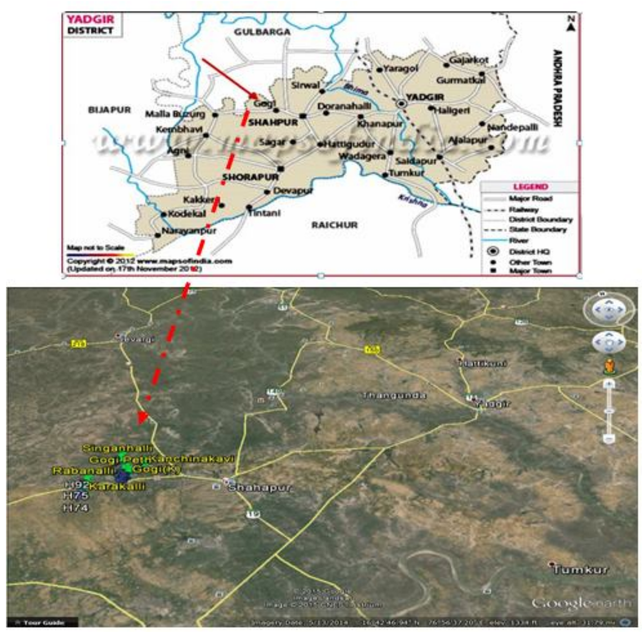

Fig. 1. Map showing the Villages covered in the Gogi Region

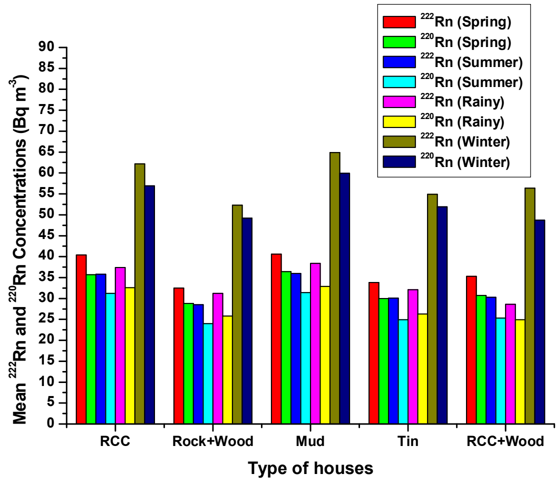

Fig. 2. Seasonal variation of ^{222}Rn and ^{220}Rn concentrations for the different type of houses