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ESTIMATION OF ANNUAL INHALATION DOSE DUE TO RADON, THORON AND THEIR PROGENY CONCENTRATIONS IN THE INDOOR DWELLINGS

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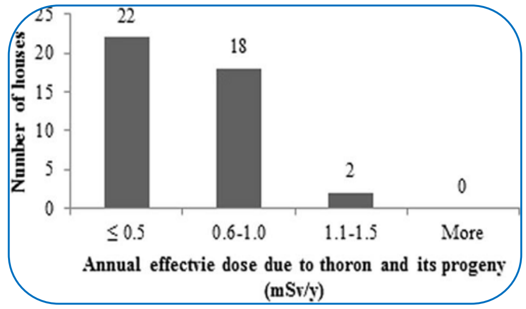
ABSTRACT :

This paper represents the indoor radon and thoron concentration measurements in dwellings located in the Gogi region, Yadgir district, Karnataka, India. The dwellings were so chosen that they were within 5km range from the Uranium mining area. The monitoring was performed for 3 months using 100 set of detectors comprises of the pin holes based dosimeter and Direct radon or thoron progeny sensors in the living rooms and bed rooms of 100 dwellings of different construction types selected from the region. A passive time-integrated measuring technique was applied by using Solid State Nuclear Track Detectors (SSNTDs) based LR-115 films as detectors. Mean annual inhalation dose of the present region varied from 1.4 to 2 mSv y^{-1} *with a mean of 1.7 mSv y*$^{-1}$*. The data obtained in the present study will provide the future researchers a baseline data for comparison and further environmental radioactivity research of the study region.*



KEYWORDS : *inhalation dose, radon, LR-115, progeny, thoron.*

INTRODUCTION

Radon is a naturally occurring radioactive gas generated by the decay of uranium and thorium bearing minerals in rocks and soils. Radon and its decay products are the major contributors to human exposure from natural radiation sources (Chen et al. 2012). Radon (^{222}Rn) and thoron (^{220}Rn) gases enter the indoor air through exhalation from soil and building materials used in walls, floors and ceilings (Sahoo et al. 2013). Radon and thoron are two main sources of natural radioactivity in the atmosphere out of which radon contributes more than half of all non-medical exposure to ionizing radiation dose received by general population (Avinash et al. 2014a and Rohit et al. 2013).

The study is of importance because the dwellings were so chosen that they were within 5km range from the Uranium mining area. The contribution of indoor thoron concentration is generally considered negligible because of its short half-life (Rawat et al. 2011). But in the present work the contribution of thoron is not negligible because of its high concentration in the indoor atmosphere and is may be due to the building materials used for the construction of dwellings.

The area covered for the study is Gogi region of Yadgir district lies in the northern-part of Karnataka between 16^{o} 11'- 16^{o} 50' N Latitudes and 76^{o} 17' - 77^{o} 28' E Longitudes, with a geographical area of 5234.4 Sq.km. The northern part of the district represents a plateau, typical of Deccan Trap terrain and is deeply indented with ravines. The soil types in the district are deep black, medium black soil, shallow soil and lateritic soil. The deep & medium black soil covers practically the entire district's area, except a small portion towards the northern part of the district. Lateritic soil occurs in small extent towards the northern part of the district (Ground Water board, Yadgir and Avinash et al. 2014a). In the present work, ^{222}Rn, ^{220}Rn and their progeny concentrations were measured for the month October, 2013-January-2014. The work carried out in the present study has the data of the LR-115 films loaded pin holes based dosimeter deployed side by side with direct radon progeny sensor (DRPS) and direct thoron progeny sensor (DTPS) badges will provide the future researchers a baseline data for comparison and further environmental radioactivity research of the study region.

MATERIALS AND METHODS

In the present investigation, the radon, thoron and their progeny concentrations of Gogi region of Yadgir district, Karnataka, India were estimated (Fig. 1). A Gogi region covers a total of six villages namely Gogi (K), Gogi Peth, Singanahalli, Karkalli, Rabanalli, and Kanchinakavi, where the 100 pin holes based dosimeter along with DTPS/DRPS badges were deployed (Fig. 2). A passive technique using solid state nuclear track detector was used for measurements. This technique gives the average value of long-term exposure due to randomness in the radioactive decay (Mukesh et al. 2014). A radon-thoron mixed field dosimeter i.e. the pin holes based dosimeter was used for the measurement of radon and thoron separately. A solid state nuclear track detector was used as detector in this dosimeter i.e. the LR-115 film, made of cellulose nitrate. There are two films were loaded in the dosimeter for measuring the radon and thoron separately. Along with this dosimeter, Direct Radon or Thoron Progeny Sensors were kept for the measurement of progenies of radon and thoron separately. A total of 100 set of both dosimeters were installed in the different types of dwellings of Gogi region such as Reinforced Concrete Construction (RCC), Mud, Rock+Wood, Tin and RCC+Wood. These films were exposed for a period of about 90 days. A dosimeter set installed were at a height of 2m from the ground level and at least 30 cm away from any surface/wall.

After the exposure for 3 months the detectors were retrieved and some of the exposed films of the Gogi region were taken to the Radon/Thoron Progeny Research Laboratory, RP&AD, BARC, Mumbai for the analysis. The data obtained in this laboratory are verified in our laboratory. Intercomparison calibration exercises were also conducted to verify the correctness of the methodologies adopted. The data obtained by passive methods were also compared with the active methods using commercially available instruments and were found to be comparable. The films were etched using 2.5 N NaOH solution at 60°C for 90 min without stirring (Avinash et al. 2014b). 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 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 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})$^{-1}$ respectively (Vanchhawng et al. 2011). For wire-mesh capped DTPS and 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 effective dose (A_{ID}) of the present study region is calculated using the following relation

$$A_{\mathrm{ID}}\,(\mathrm{mSv\ y^{-1}}) = (C_{\mathrm{Rn}} \times 0.17 + C_{\mathrm{Tn}} \times 0.11 + EEC_{\mathrm{Rn}} \times 9 + EEC_{\mathrm{Tn}} \times 40) \times 8760 \times 0.8 \times 10^{-6}$$

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 (Mukesh et al. 2014 and Avinash et al. 2014b), 8760 h per year is the indoor occupancy time, 0.8 is the Indoor occupancy factor.

RESULTS AND DISCUSSION

In the present study, the work is carried out in the indoor environment where the concentrations of the radon, thoron and their progenies with the annual inhalation dose kept in the dwellings of the six different villages Gogi region have been calculated and are tabulated in the Table 1. The study was conducted for measuring the cumulative exposure for a minimum period of about 90 days in each house covering 100 houses where the ^{222}Rn, ^{220}Rn and their progeny concentrations were measured for the month October, 2013 - January, 2014. These results support studies, showing equal concentration of thoron in comparison with radon (Table 1).

The ^{222}Rn and ^{220}Rn and their progeny concentrations have been measured in different type of dwellings located in the Gogi region and the values were found to be within the permissible limits (UNSCEAR 2000). The attached fraction of progeny concentration marked as EEC_{WRn} for radon and EEC_{WTn} for thoron in Table 1 was also found to be very close to the total progeny concentration. This indicates very low unattached fraction. The graphs were plotted using the mean concentrations of radon, thoron and their progeny versus the no. of houses in Fig. 3-4.

The ^{222}Rn, ^{220}Rn and their progeny concentrations were measured in the dwellings of the Gogi region of Yadgir district covering six villages where the 100 pinholes dosimeter along with DTPS/DRPS were deployed. The mean values of ^{222}Rn, ^{220}Rn, and their progeny activity concentrations along with dose rates in the different locations of Gogi region are summarized in Table 1. The arithmetic mean of ^{222}Rn concentration (C_{Rn}) of Gogi region varies from 47.5 ± 8.1 to 65.1 ± 14.9 Bq m^{-3} with a total mean of 57.3 ± 10.1 Bq m^{-3}, whereas for ^{220}Rn concentration (C_{Tn}) of Gogi region it varies from 45.1 ± 8.8 to 60.5 ± 12.4 Bq m^{-3} with a total mean of 52.8 ± 9 Bq m^{-3}.

The arithmetic mean of ^{222}Rn progeny concentration (EEC_{Rn}) of Gogi region varies from 14.7 ± 2.5 Bq/m^3 to 21.4 ± 3.9 Bq m^{-3} with a total mean of 17.7 ± 3.1 Bq m^{-3}, whereas for ^{220}Rn progeny (EEC_{Tn}) of Gogi region varies from 1.4 ± 0.2 Bq m^{-3} to 1.8 ± 0.5 Bq m^{-3} with a total mean of 1.6 ± 0.4 Bq m^{-3}. The arithmetic mean of annual inhalation dose of Gogi region varies from 1.4 ± 0.2 Bq m^{-3} to 2 ± 0.5 Bq m^{-3} with a total mean of 1.7 ± 0.3 Bq m^{-3}.

Fig. 5 shows the correlation between ^{222}Rn and ^{220}Rn concentrations, which was approximately linear with a correlation coefficient of 0.991. Also Fig. 6 shows the correlation between ^{222}Rn and ^{220}Rn progeny concentrations, which was approximately linear with a correlation coefficient of 0.92 (Sivakumar et al. 2010).

In the present study, the thoron concentration was also found to be higher as radon concentration. The higher value of thoron in the present region may be due to presence of high concentration of natural radionuclide minerals in the local geological formations and the building materials used for the construction. The high value of radon and thoron progeny concentrations with time-integrated measurements indicates that long time exposure of radon and thoron progenies to the human beings can produce high radiation doses. An annual inhalation dose rate was also measured in indoor environment of the study area. The mean annual inhalation dose in the present study was found to be 1.7 mSv which is near the permissible limits (UNSCEAR 2000). The ratio of radon and thoron with their respective progenies constitute for an Equilibrium Factor was also determined. The mean equilibrium factor for radon (F_R) in the present region was found to be ranging from 0.3±0.02 to 0.35±0.1 with a total mean of 0.32±0.04 [Vanchhawng et al. 2011 and Mishra et al. 2014]. The total mean equilibrium factor for thoron (F_T) in the present region was found to be 0.03±0.004 [Chen Jing et al. 2012 and Harley et al. 2010]. This shows that, the data measured in the present region are in good agreement with the literature results (Ramachandran et al. 2003). The results shows dose due to overall concentration of radon, thoron and their progeny in the study area are low compared to that of the level found in high background radiation areas like the western coast of Kerala [Chougaonkar et al. 2010].

CONCLUSION

The fourth set of simultaneous long time mean radon, thoron and progeny concentration measurements were carried out in around 100 dwellings of Gogi region during the month October, 2013 – January, 2014. The thoron concentrations were observed to be almost equal to radon gas concentrations.

The progeny concentrations were found to be in the same range as reported in other regions. The analyses of the successive sets are in progress. The mean annual inhalation dose in the present study is found to be 1.7 mSv. Hence it is concluded that, the radon, thoron and their progenies constitute more than 50% of total natural background radiation dose received by a man. A Significant correlation with correlation coefficient of 0.991 was observed between radon and thoron whereas 0.92 was observed between radon and thoron progeny concentrations in this study. These results support studies, showing higher concentration of radon in comparison with thoron. Due to the higher concentration of thoron, the contribution to the total dose by thoron was also found to be more. This shows that the radiation doses produced by thoron and its progeny cannot be neglected in epidemiological studies because sometimes they can be more significant contributors than radon due to their high concentration and dose conversion factors.

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Table 1. The mean ^{222}Rn, ^{220}Rn and their progeny concentrations of Gogi region.

S No.	Sample Location	House Number	Mean±SD								
			C_{Rn} (Bq m^{-3})	C_{Tn} (Bq m^{-3})	EEC_{Rn} (Bq m^{-3})	EEC_{Tn} (Bq m^{-3})	EEC_{WRn} (Bq m^{-3})	EEC_{WTn} (Bq m^{-3})	A_{ID} (mSv y^{-1})	Equilibrium Factor F_R	F_T
1	Gogi (K)	1-32	65.1±14.9	60.5±12.4	21.4±3.9	1.8±0.3	19.8±3.6	1.7±0.3	2±0.3	0.35±0.1	0.03±0.003
2	Gogi Peth	33-62	58.8±9.6	53.7±8.2	17.4±2.9	1.5±0.2	16.3±2.8	1.5±0.2	1.6±0.3	0.31±0.05	0.03±0.004
3	Singanahalli	63-71	47.5±8.1	45.1±8.8	14.7±2.5	1.4±0.2	13.6±2.4	1.3±0.1	1.4±0.2	0.31±0.03	0.03±0.004
4	Karakalli	72-81	59.1±11.4	54.1±9.5	18±2.8	1.6±0.2	17.1±2.8	1.5±0.2	1.7±0.2	0.32±0.03	0.03±0.005
5	Rabanalli	82-96	58.2±9.6	53.3±10.3	18.5±3.2	1.7±0.3	17.4±3.2	1.6±0.3	1.7±0.3	0.33±0.04	0.03±0.003
6	Kanchinakavi	97-100	55.1±6.9	50.3±4.6	16.5±3.4	1.6±0.3	15.5±3.6	1.5±0.3	1.6±0.3	0.3±0.02	0.03±0.004
Mean±SD			**57.3±10.1**	**52.8±9**	**17.7±3.1**	**1.6±0.2**	**16.6±3.1**	**1.5±0.2**	**1.7±0.3**	**0.32±0.04**	**0.03±0.004**

SD – Standard Deviation

Figure Captions:

Fig. 1. The map showing the location of the study area

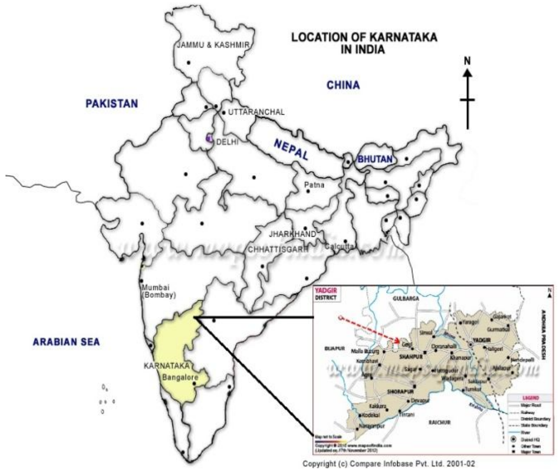
Fig. 2. The Garmin GPS map showing the number of dwellings selected in the Gogi Region

Fig. 3. The mean ^{222}Rn and ^{220}Rn concentrations of the Gogi region

Fig. 4. The mean ^{222}Rn and ^{220}Rn progeny concentrations of the Gogi region

Fig. 5. Correlation between the radon and thoron concentrations

Fig. 6. Correlation between the radon and thoron progeny concentrations



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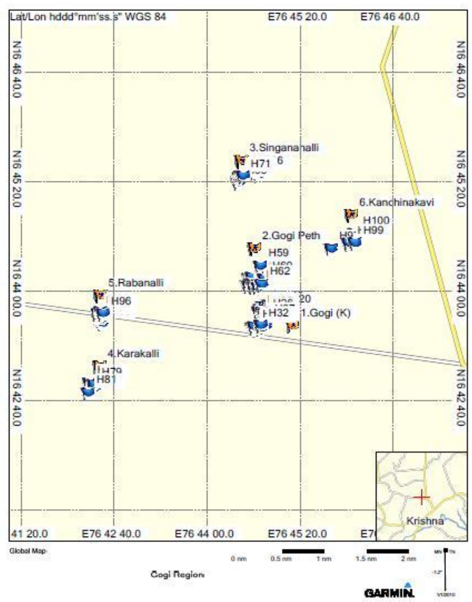


Fig. 2. The Garmin GPS map showing the number of dwellings selected in the Gogi Region

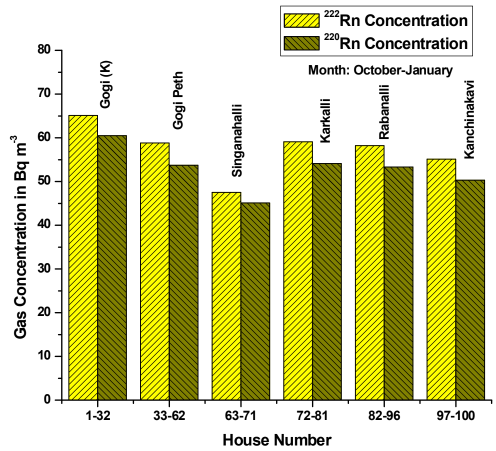


Fig. 3. The mean ^{222}Rn and ^{220}Rn concentrations of the Gogi region

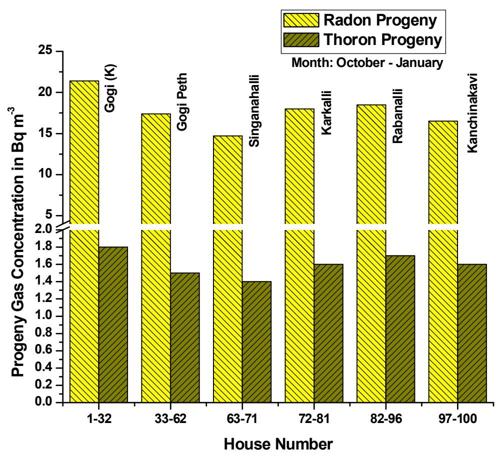
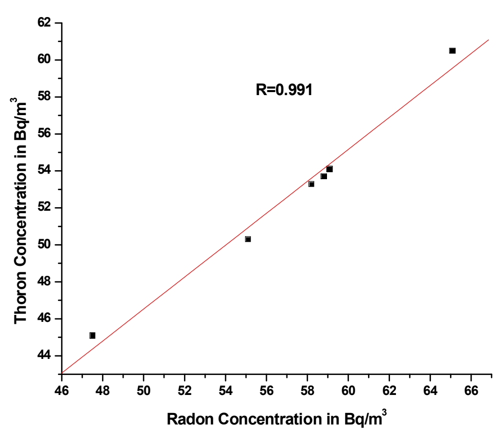


Fig. 4. The mean ^{222}Rn and ^{220}Rn progeny concentrations of the Gogi region



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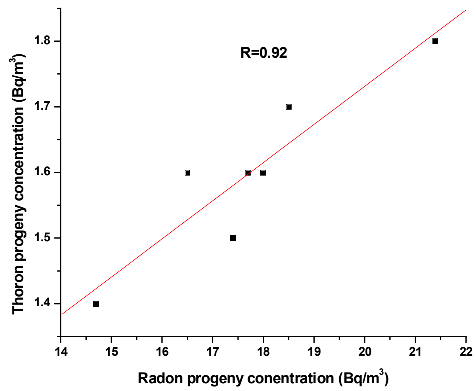

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