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A study on radon and thoron progeny levels in dwellings in South India

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Background: Decay products of radon and thoron present in indoor environment are the most important sources of radiation from natural sources which affect human beings, since general public spend at lest 80% of their time in indoor. *Materials and Methods:* Air samples were collected for measuring the concentration of radon and thoron daughter products from various indoor environments during four different seasons of the year from the Gudalore taluk of Nilgiri Biosphere using high volume air sampler. The concentration of decay products of radon and thoron were estimated using an alpha counter. *Results:* Studies have revealed that the annual average potential alpha energy concentrations of radon and thoron progeny in dwellings of Gudalore were recorded as 3.54 and 2.65 mWL respectively. It was also observed that the potential alpha energy concentration (PAEC) values for radon progeny undergo dramatic change with the change of season perhaps due to different aerosol contents in the air. The maximum ^{222}Rn (3.93 mWL) and ^{220}Rn (3.10 mWL) progeny concentrations were observed during winter months and the minimum values (^{222}Rn 3.14 mWL and ^{220}Rn 2.20 mWL) were observed during summer. *Conclusion:* Studies have shown that the dwelling with mud wall registered high value of radon and thoron progenies (5.49 mWL and 3.88 mWL). While low values were observed in dwellings with vinyl floor. High concentrations of radon and thoron progeny were observed between 3.00 to 5.00 Hrs, while low values were observed at 14.00 hrs. Studies suggest that radiation emission from radon and thoron daughter in the study area were remained well below the recommended level. **Iran. J. Radiat. Res., 2010; 8 (3): 149-154**

Keywords: *Radon, thron, progeny, seasonal variation, diurnal variation etc.*

INTRODUCTION

Short-lived radon and its decay products are the most important sources of radiation from natural sources which affect human beings. About one third of the total radiation dose received is due to inhalation of short – lived radon progeny in the indoor environment [1]. Naturally occurring radioactive inert gases, radon and its radioactive particulate progeny are the main cause of health hazard under a variety of situations, ranging from underground mines to indoor air in dwellings. ^{222}Rn and ^{220}Rn are the products of ^{238}U and ^{232}Th decay series, and as such both are always present in small concentrations in many geological formations. Historically ^{222}Rn and ^{220}Rn are called as radon and thoron, respectively. ^{222}Rn decays with a half-life of 3.83 days by alpha emission to a series of particulate progeny. These particulate progeny (of ^{222}Rn) are also radioactive and decay through a series of alpha and beta emissions. ^{220}Rn also decays by alpha emission with a half-life of 54.6 s to a series of particulate progeny having similar but different half-lives and emissions than the progeny of ^{222}Rn. Although the decay products of ^{222}Rn are the dominant source of radiation exposure. Evidence indicates that the equivalent radiation dose from thoron (^{220}Rn) and its progeny is about 5%-30% of that due to ^{222}Rn and its progeny [1, 2]. The distribution of excessive concentration of radon also depends on the geology and geography of the place, and exhibit significant variations across relatively short distances.

In most radon exposure studies, contribution of ^{220}Rn is usually neglected. The reasons which are attributed may include: (1) Concentration of ^{220}Rn is generally much lower than the concentration of ^{222}Rn and (2) ^{220}Rn has a relatively short half life than ^{222}Rn (54.6 s (^{220}Rn) vs 3.83 d (^{222}Rn)). Hence ^{220}Rn might have decayed significantly before emanating from the soil. But in places such as Gudalore, the soil and rocks have greater concentration of ^{232}Th [3]. Therefore it is inappropriate to neglect ^{220}Rn. Present studies on ^{220}Rn were made with a view (i) to measure the radon

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and thoron daughter progeny predicts from various indoor environments during different seasons of the year and also (ii) to study the effect of floor and wall covering materials and aldo (iii) in their diurnal variations during different seasons of the year.

Study area

Gudalore is a highly populated area situated in western ghats in South India with their center at 11°30" N, 076°30" E. Gudalore is also known for its splendidly beautiful environment and it is at the lower end of western slope of Western Ghats, which is one of the oldest and important eco-system in India. It is a hilly region where the altitude varies from 750-1240 m above mean sea level. People in hilly region spend about 80% of their life time in indoor environment with limited ventilation. Hence, the knowledge of indoor radon and thoron progeny concentration is essential to evaluate the total inhalation dose received by the general public living in this region. To the best of my known information on background radon and thoron progeny levels for this region is not available in literature. Hence, it was considered imperative to measure the indoor and outdoor levels of radiation emitted from radon and thoron progeny in and around Gudalore (figure 1).

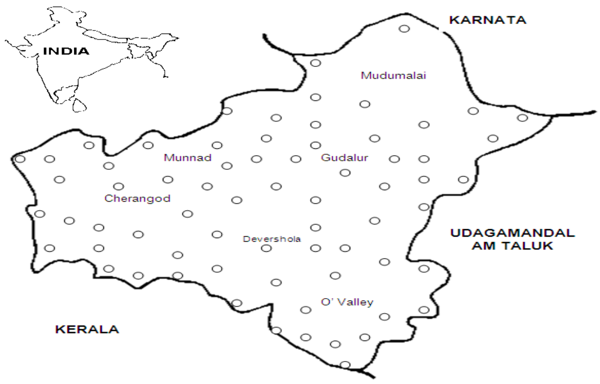

Figure 1. Sampling stations in the study areas of Gudualur, Nilgiri biosphere of peninsular India.

MATERIALS AND METHODS

High efficiency and low background and portable alpha counting systems made the counting process easy and therefore it was used in these studies for measuring the radioactivity. Among the number of techniques available, grab sampling method is considered to be the best method for the measurement of instantaneous concentrations of decay products of radon, thoron and their progeny in air [4, 5]. Grab sampling methods involves collection of airborne decay products on a filter paper and then counting the deposited progeny activity mostly using alpha counter or spectrometer [6, 7]. Staplex high volume air sampler (Model (TFIA2)) was used to draw air samples. Air sampling was done for 10 minutes and 3 to 5 samples were collected from each location. A total of 195 locations were selected. The air samples were collected by drawing air through a glass-fiber filter paper having thickness of 4.5 g/cm^2 (1mm) and diameter 10.5 cm. The aerosol was collected on a circular port of 8.9 cm diameter. After completion of sampling, alpha activity of the sampled filter paper was measured on ZnS (Ag) based scintillation counter consisting of ZnS(Ag) alpha probe (ECIL 1185) coupled to a Geiger counting system (PLA, GCS 101). The counting procedure as described by Stranden [8] was followed and the radon and thoron daughter concentrations were calculated as follows. and this study performed in each locations.

$$WL_{Rn} = \frac{I^{decay\ (1)} - k \times I^{decay\ (2)}}{F_{Rn} \times V}$$

$$WL_{Tn} = \frac{I^{decay\ (2)}}{F_{Tn}} \times V$$

Where:

WL_{Rn} & WL_{Tn}: are concentrations expressed in working level (WL) of radon and thoron daughter respectively

$I^{decay(1)}$ & $I^{decay(2)}$: are the mean alpha activity on the filter in disintegration /minute in the counting period 1 and 2 respectively

V: volume of air sampled

F_{Rn} & F_{Tn}: factors to convert from alpha disintegration /minute to WL

Sampling for radon and thoron progeny concentrations in Gudalore dwellings were undertaken during different seaons of the year viz; winter (December - February), summer (March - May), spring (June - August) and autumn (September – November).

RESULTS AND DISCUSSION

Statistics of radon and thoron progeny concentration

The arithmetic mean, range, standard deviation, skewness and kurtosis coefficients of radon and thoron progeny levels from dwellings were recorded (tables 1 and 2). Measurements and distribution of indoor radon and thoron daughter concentrations revealed approximately log-normal. Existence of high level of radon and thoron daughter in some dwellings showed skewed distribution. The annual average of radon daughter concentration was found to be 3.54 ± 1.01 mWL. The minimum values (0.74 mWL) were observed in a dwelling with painted walls and plastic (vinyl) floor located at pattavayal during summer, while the maximum values (7.64 mWL) were measured in a mud dwelling at 9th Mile (name of a place) during winter months. The annual average concentration of thoron daughter was found to be 2.65± 1.15 mWL. The minimum values (0.48 mWL) were observed with painted walls and tile flooring at a dwelling situated in Health Camp area during summer months. In a mud dwelling, located at Kil-Nadugani, the maximum values (6.38 mWL) were seen during winter months, where highest ^{232}Th contents were observed in an earlier study conducted by Selvasekarapandian *et al.* (3).

Table 1. Statistics of Radon progeny levels in different dwellings.

Statistics	Winter	Summer	Spring	Autumn	Annual
Mean	3.93	3.14	3.40	3.70	3.54
Standard Deviation	1.68	1.61	1.63	1.66	1.01
Minimum	1.42	0.74	0.84	0.94	0.99
Maximum	7.64	6.84	7.25	7.44	7.29
Skewness	0.39	0.44	0.48	0.36	0.42
Kurtosis coefficient	-0.82	-0.80	-0.64	-0.83	-0.77
Frequency distribution	Log-Normal	Log-Normal	Log-Normal	Log-Normal	Log-Normal

Table 2. Statistics of Thoron progeny levels in different dwellings.

Statistics	Winter	Summer	Spring	Autumn	Annual
Mean	3.10	2.20	2.47	2.72	2.65
Standard Deviation	1.15	1.27	1.15	1.11	1.15
Minimum	1.17	0.48	0.74	0.65	0.84
Maximum	6.38	5.56	5.89	5.14	5.72
Skewness	0.62	0.70	0.80	0.27	0.61
Kurtosis coefficient	0.53	-0.19	0.70	-0.41	0.07
Frequency distribution	Log-Normal	Log-Normal	Log-Normal	Log-Normal	Log-Normal

Effect of building characteristics on radon and thoron progeny concentration

The Potential Alpha Energy Concentration (PAEC) values for radon and thoron in dwellings with different types of walls and floor covering materials are shown in tables 3 and 4. It was observed that a different covering material also affects differently the radiation emission from the progenies of radon and thoron [9, 10]. It is therefore, expected that the concentration of radon and thoron and their progeny will also be different for different places where different wall and floor covering materials were used. Values given in table 3 had revealed that PAEC values for radon progeny was high (5.49 mWL) for houses with mud walls, and low for the houses with walls coated with paints (2.65 mWL). Intermediate values of (3.32 mWL) radon progeny concentration were observed in case of bare walls (without paint / coatings).

Similar results were obtained in case of thoron progeny also. The highest concentration of radon and thoron progeny in mud houses may be attributed to the higher exhalation rate of radon and thoron [11]. High radon and thoron progeny levels in mud houses may be attributed to poor ventilation as these houses do not have sufficient number of windows and doors for ventilation. Concrete surface without any covering materials exhibited high exhalation of radon and thoron [9, 10]. These results are consistent with the earlier observations of many workers [9, 10]. Low radon and thoron progeny levels were observed in dwellings with paint coated walls in the present studies which may be attributed to the concentration and size of pores on concrete surface which get reduced due to paint coatings and hence resulting in reduction in exhalation rate of radon and thoron. It can be observed from table 4, that the PAEC values for places using plastic (vinyl) and wood as floor covering materials were lower than those dwellings with bare floor (without covering materials) and mud floors. Yu *et al.* [10] has already reported that plastic is the most effective material to inhibit radon exhalation from the floor, while concrete surfaces without covering materials and mud floors have highest radon exhalation rates. This may be the reason for low radon and thoron progeny levels in houses with plastic floor covering. Less pore intensity in case of tiles also results in low exhalation rates of radon and thoron, hence low concentration of radon and thoron progeny levels were observed in tile flooring houses. Since, wood does not contain any radioactive materials, therefore it cannot act as a source of radon and thoron progeny, and however this may act as inhibitor to radon and thoron gas. The inhibition property of wood is not as good as that of plastics, further it also depends on the thickness of the wood and also half life of the radioactive materials [12]. This is evident from higher levels of radon and thoron progeny in wooden houses than that seen in with Plastic (vinyl) flooring.

Table 3. PAEC values for radon and thoron progeny in dwellings of different wall covering materials.

Wall Covering	PAEC (mWL)	
	Radon	Thoron
Mud	5.49±0.93	3.88±1.0
Bare	3.32±1.33	3.03±0.61
Painted	2.65±1.28	1.53±0.43

Table 4. PAEC values for radon and thoron progeny in dwellings of different floor covering materials.

Floor Type	PAEC (mWL)	
	Radon	Thoron
Mud	5.49±0.93	3.88±1.00
Bare (Cement)	4.01±1.21	2.78±0.75
Tiles	2.66±0.53	2.45±0.74
Vinyl	1.31±0.35	1.22±0.07
Wood	2.04±0.41	1.28±0.35

Seasonal variations in PAEC (potential alpha energy concentration) levels of radon and thoron

The radon and thoron progeny concentrations were monitored using two count method at three month intervals for one year to quantify the seasonal variations (figure 2). Radon and thoron daughter levels were high during winter months than those seen during the rest of the year. Maximum concentrations of radon and thoron daughters were observed during winter with a mean value of 3.93 mWL and 3.10 mWL respectively, while minima occurred during summer season with a mean value of 3.14 mWL and 2.20 mWL respectively. Mean values for autumn were 3.70 mWL and 2.72 mWL respectively. For spring season the values of radon and thoron progeny were 3.40 mWL and 2.47 mWL respectively. Low temperature in winter perhaps may be responsible for reduction in the equivalent mixing height, which might be limiting the vertical diffusibility of radon, thoron and their progeny, resulting in high concentrations at the ground level. The low values of radon and thoron progeny levels during summer may be attributed to relatively high prevailing temperatures, which perhaps elevate the equivalent mixing height and hence resulting in increase in dilution. To protect from low temperature during winter [i.e. 2°C - 15°C], the doors and windows of most of the houses are kept closed for most of the times of a day, which perhaps reduces the exchange of air inside the house. This perhaps may be the reason for high level of radon and thoron daughters inside the houses during this season.

Diurnal variation in PAEC levels of radon and thoron

Figure 3 shows the diurnal variations in radon and thoron progenies in dwellings of Gudalore. Diurnal trends of radon in air in this region are well explained by the hypothetical conditions, which states that at night, radon, thoron and their progenies are mostly remain bound with the lower atmosphere due to low temperature, and thus concentrations of radon and thoron progeny levels increase. The maxima in the values of radon and thoron progeny were observed before sunrise i.e. between 03.00 - 05.00 hrs local standard time (IST) at Gudalore. After sunrise, solar radiation warms the ground, which in turn warms the atmosphere, as a consequence, vertical mixing increases which leads to a substantial decline in ground level concentration of radon and thoron daughter concentration in the afternoon, with minimum values at about 14.00 hrs IST at Gudalore. In principle, this behavior had been observed worldwide [13]. In the long term, at Gudalore the diurnal maximum to minimum ratio is 1.4 in winter and 2.6 in the summer. On an average this ratio was found to be 2. Figure 4 shows the correlation between ^{222}Rn and ^{220}Rn concentrations, which was approxi-

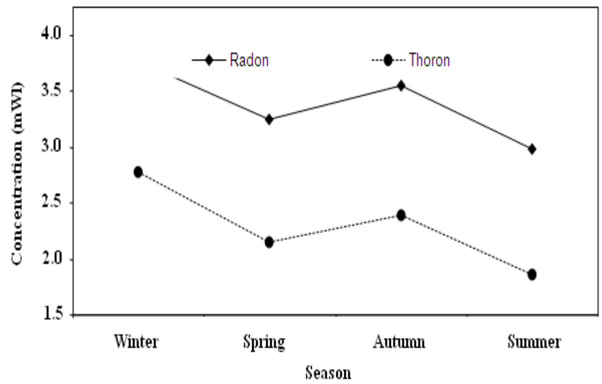

Figure 2. Seasonal variations in radon and thoron daughter concentrations.

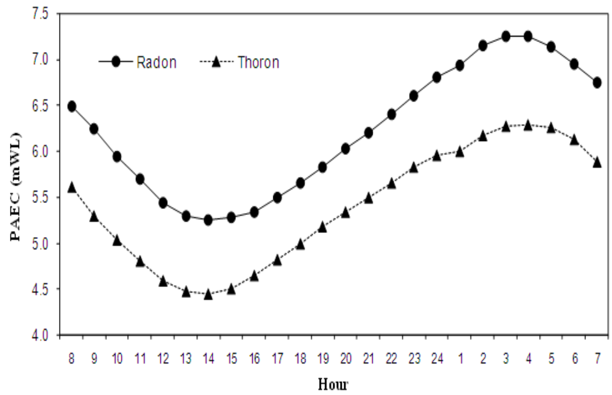

Figure 3. Diurnal variations in radon and thoron progeny in dwellings of Gudalur.

mately linear with a correlation coefficient of 0.775. The concentration of ^{220}Rn increases with that of ^{222}Rn and the observed concentration of former was 0.72 times that of the latter.

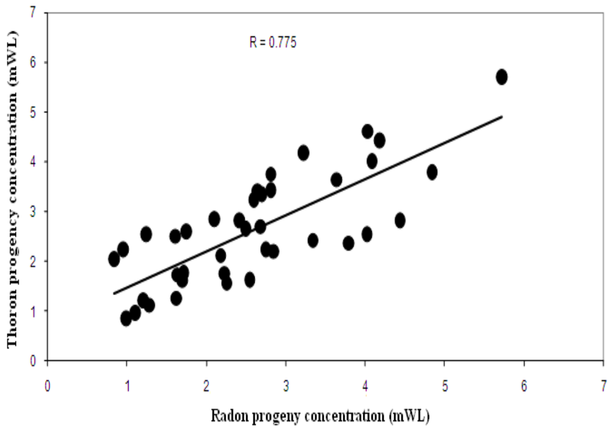

Figure 4. Correlation between the radon and thoron progeny concentrations.

CONCLUSION

- The annual average radon progeny levels in indoor air in Gudalore range was between 0.99 to 7.29 mWL and that of thoron progeny varied from 0.84 to 5.72 mWL.
- Radon and thoron progeny levels in indoor atmosphere showed seasonal variations. Maximum values 3.93 mWL, and 3.10 mWL were observed during winter and summer respectively. During these seasons minimum values were 3.14 mWL and 2.20 mWL respectively.
- Generally, ambient radon and thoron progenies attained minima in the afternoons between 12.00 - 14.00 hrs (IST) and the highest values were observed in the morning hours before sunrise i.e. between 3.00 - 5.00 hrs (IST).
- Significant correlation with correlation coefficient of 0.775 was observed between radon and thoron progenies in this study.

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