

## Variation of radon progeny concentration over a continental location

K. Charan Kumar<sup>1</sup>, T. Rajendra Prasad<sup>2</sup>, T. Narayana Rao<sup>2</sup>,  
M. Venkataratnam<sup>2</sup>, K. Nagaraja<sup>1\*</sup>

<sup>1</sup>Atmospheric and Space Science Research (ASSR) Lab, Department of Physics, Bangalore University, Bangalore 560 056, India

<sup>2</sup>National Atmospheric Research Laboratory, Gadanki, 517 112, India

### ABSTRACT

#### ► Original article

**\*Corresponding author:**

Dr. Kamsali Nagaraja,  
Fax: + 91 80 2321 9295  
E-mail:

kamsalinagaraj@bub.ernet.in

Revised: March 2015

Accepted: May 2015

Int. J. Radiat. Res., April 2016;  
14(2): 105-111

DOI: 10.18869/acadpub.ijrr.14.2.105

**Background:** The variation of the radon progeny concentration in outdoor environment and meteorological parameters at fine resolution were studied for one year at a continental location, National Atmospheric Research Laboratory, Gadanki, India. **Materials and Methods:** The concentrations were measured using Alpha Progeny Meter by collecting air samples at a height of 1 m above the Earth's surface at a known flow rate. **Results:** Radon progeny concentration shows temporal variations on diurnal and monthly scales, and is due to mixing in the atmosphere. Peak in the early morning hours and low values during afternoon compared to nighttime are due to differential heat contrast between earth's surface and its atmosphere. However, the activity during February shows maximum compared to June/July months. The diurnal variation of radon progeny shows positive correlation with the relative humidity and negative correlation with ambient temperature. The monthly mean activity of radon progeny for the year 2012 was found to be  $4.76 \pm 0.73$  mWL. **Conclusion:** The mean concentration of radon progeny in the study region is relatively high compared to the other locations in India and may be due to the rocky terrains and trapping of air-masses near the observation site due to its topography.

**Keywords:** Radon progeny, NARL, alpha progeny meter, working level.

### INTRODUCTION

Close to the Earth's surface, over continental regions, the ionizing radiation is mainly due to the radioactive materials from Earth's surface and galactic cosmic rays of extraterrestrial origin that leads to the ionization of air <sup>(1)</sup>. The rocks and soil in the solid earth contain radioactive elements such as uranium, radium, thorium, etc. and their concentrations vary from region to region. Within the planetary boundary layer, radiation from radioactive gases such as radon exhaled from the Earth's surface and their progeny predominantly ionize the atmosphere <sup>(2-4)</sup>.

Radon is a long lived gas product of the

natural radioactive decay of radium that is the decay product of primordial radioactive nuclei uranium, which occurs naturally in the earth's crust. The principal decay modes and half-lives of <sup>222</sup>Rn and its short-lived progeny in order are <sup>222</sup>Rn- $\alpha$ , 3.82 days; <sup>218</sup>Po- $\alpha$ , 3.05 m; <sup>214</sup>Pb- $\beta$ , 26.8 m; <sup>214</sup>Bi-  $\beta$ , 19.7 m and <sup>214</sup>Po-  $\alpha$ , 200 ms, of major concern. The radiations such as  $\alpha$ ,  $\beta$  and  $\gamma$  were emitted during the decay of radon and its progeny cause ionization in the atmosphere. Radon decay products tend to collect on the aerosol particles in the atmosphere and when inhaled, the dose for the respiratory tract and the lungs is predominantly caused by the deposition of radon progeny attached to aerosols. The  $\alpha$ -particles emitted by the decay of

deposited radon daughters interact with the sensitive lung tissues, and of prolonged exposure may lead to malignant transformation, which may result in lung cancer (5-9).

Radon ( $^{222}\text{Rn}$ ) atoms from the terrestrial radio nuclide  $^{238}\text{U}$  are transported through the subsoil pore spaces and, while an amount of them will decay, the rest will be released into the atmosphere. The amount of radon depends on the amount of  $^{238}\text{U}$  in the ground and is influenced by the type, porosity, dampness and temperature of the soil cover. Radon has a long half-life of 3.823 days. However, its decay products are typically short-lived, so they follow the distribution of radon. The only long-lived product is  $^{210}\text{Pb}$  with a half-life of 22.3 years. Radon and its short-lived daughters  $^{218}\text{Po}$ ,  $^{214}\text{Pb}$ ,  $^{214}\text{Bi}$  and  $^{214}\text{Po}$  are also valuable as natural tracers in the troposphere, in particular at the boundary layer near to the ground. In the present study, the importance is given only to the alpha emitting radon progenies i.e.  $^{218}\text{Po}$  and  $^{214}\text{Po}$ . Due to the inhalation of progenies and high ionization power of  $\alpha$ -particles emitted during decay, the existence of progenies may damage the lung cells to a greater extent (10).

Even though, the extensive study on atmospheric aerosols has been conducted at National Atmospheric Research Laboratory, Gadanki, which is a rural site and free from the anthropogenic activities. The measurement of radon and aerosol attached radon progeny concentrations were not reported till date. Hence, in 2012, a campaign was conducted to study the activity concentrations of aerosol attached radon progenies and its behavior with associated meteorological parameters. This paper presents the preliminary results obtained in 2012, with an intention to extend our understanding of the activity of aerosols attached radon progeny concentrations in the typical tropical region in relation to the weather parameters and their correlation.

## MATERIALS AND METHODS

### Methodology and study area

The alpha emitting radon progeny concentrations that were attached to aerosols

were measured using Alpha Progeny Meter developed by Saphymo GmbH (formerly known as Genitron Instruments, Germany) (figure 1). Air is drawn through a glass micro-fiber filter paper of pore size  $0.5\ \mu\text{m}$  with a constant flow rate of 2 liters per minute and alpha counted using CANBERRA made CAM300AM semiconductor detector unit with a sampling frequency of 10 minutes. The air flow rate and sampling period were maintained constant throughout the campaign. At the end of the sampling period, the accumulated alpha counts are fed to the acquisition system (11). The alpha activity of radon progenies were expressed in Working Level (WL), where 1 WL corresponds to potential alpha energy of all short-lived radon daughters in equilibrium with radon concentration of  $3700\ \text{Bq m}^{-3}$  (12).

Continuous observations were carried out at the National Atmospheric Research Laboratory (NARL), Gadanki ( $13.5^\circ\text{N}$ ,  $79.2^\circ\text{E}$ ), a rural tropical warm location in peninsular India, about 2 km away from main residential areas with no major industrial activities. The locative map and topography of NARL is shown in figure 2, respectively. Gadanki region experiences both summer (Southwest) and winter (Northeast) monsoons. Overall wind direction was southerly and southeasterly during April, westerly from May to September and northeasterly during October and November (13).



Figure 1. Typical alpha progeny meter (Saphymo GmbH).

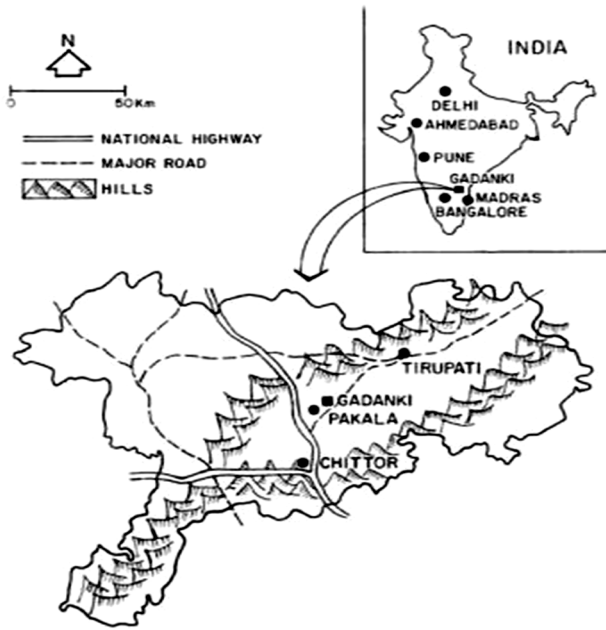


Figure 2. Location of NARL, Gadanki, India.

## RESULTS AND DISCUSSION

The observed diurnal variation of radon progeny concentration at a height of 1m above earth's surface is shown in figure 3. The concentration is observed for some of the typical days covering all the seasons and the concentration shows peak during the early morning hours (04–09 hrs of IST) and minima during afternoon hours (14–18 hrs of IST). The higher activity of radon daughters in air during morning at the ground level may be attributed to the formation of temperature inversion, which traps the atmospheric constituents including radon progenies within planetary boundary layer and minimum concentration in the afternoon hours is mainly because of increased vertical mixing and rising of aerosols to the higher altitudes due to raise in

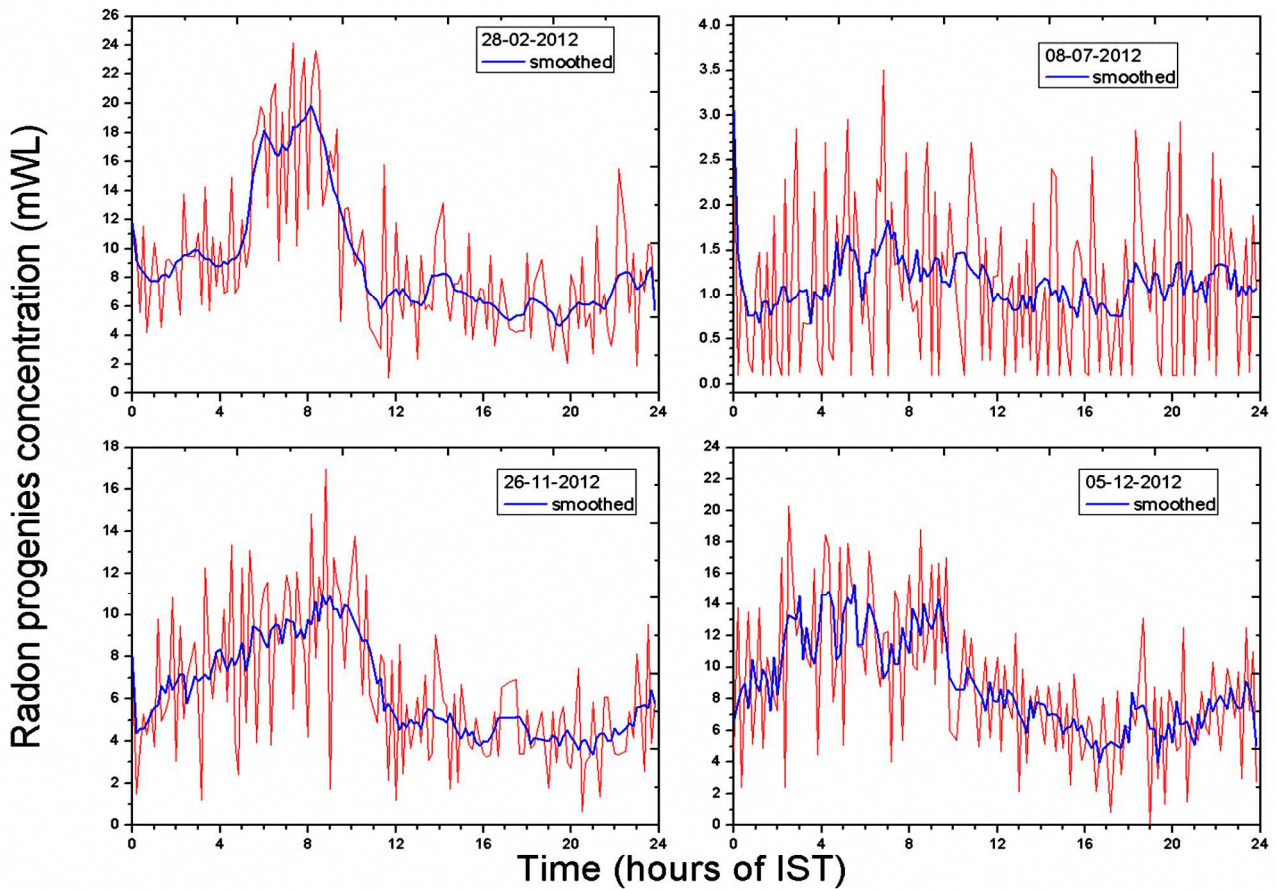


Figure 3. Diurnal variation of radon progeny concentration in different seasons. Dark line is running average of 6-points for every hour.

temperature of the atmosphere. The rapid fluctuations in the concentrations were due to local variations in wind speed and direction (14, 15). It varies from month to month or season to season depending on the weather condition and the exhalation rate of radon. The concentration will be relatively high during stable atmosphere in nighttime compared to the unstable atmosphere during daytime due to the onset of convection because of solar activity. The similar reasons were attributed to the days of winter compared to the summer seasons. However, during rainy season several parameters will influence including the washout of radon progeny due to precipitation and minimizes the buildup of radon near to the earth's surface (16).

The figure 4 shows the variation of hourly averaged radon progeny concentrations with the ambient temperature for a typical day in the month of February. The trend observed is as usual and has the same reasoning explained before for its peak in the morning hours and minimum during noon hours. In addition, the variation of temperature and relative humidity are also plotted in the same graph to see their dependences on each other and its influence on progeny concentration. The concentration of

radon progeny ranges from 1 to 24 mWL and is shows significant diurnal variations of the order 24 for 10-minutes sampling whereas for hourly averages it varies from 5 to 17 mWL with a magnitude of 4-fold variation. The average for longer period minimizes the fluctuations but maintains the trend in the variation of any of the parameters, for example, radon progeny. The observed values of the same order as observed elsewhere (7, 17).

One can clearly see an anti-correlation (43%) between radon progeny and temperature and a positive correlation (55%) with relative humidity. It reveals that the diurnal change in temperature and relative humidity has strong bearing on the variations of radon progeny concentrations near to the earth's surface trend. This positive correlation may be attributed to the increase in the concentration of attached radon progeny in air as the content of water or humidity in the lower atmosphere increases. This may be due to the reason that the aerosol particles that carry radon daughters upward have been known to be hygroscopic in nature (12). Hence, it reveals that the diurnally change in temperature at the ground level has a direct impact on the radon progeny concentration in

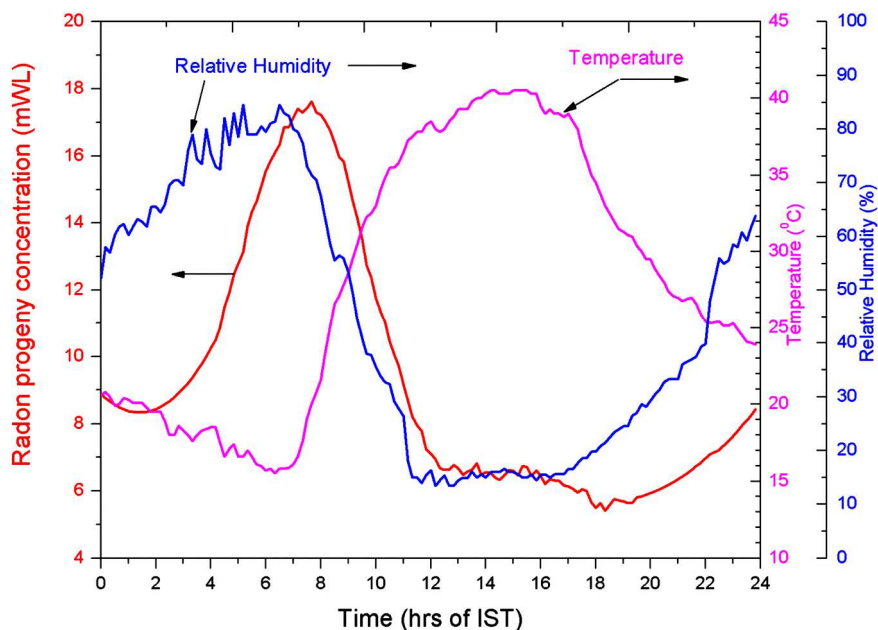


Figure 4. Variations of radon progeny concentration with ambient temperature and relative humidity.

the atmosphere <sup>(14, 15)</sup>. The diurnal variations in the concentration of radon progenies were same in all months for the entire measurement period. The average daily pattern of radon progeny concentration featured a minimum in the late afternoon and a maximum in the early morning hours. This pattern was typically observed on sunny days of all the months, when the sky was clear, both during day and night-time.

The concentration attains a maximum of  $7.82 \pm 0.36$  mWL in February and a minimum of  $0.71 \pm 0.03$  mWL in July. The concentration is relatively maximum during winter (Dec–Feb) and reduces to lower values in summer (March–May) and still low during monsoon season (June–Sept) and may be attributed to several factors such as a) intense temperature

inversion that occurs during winter season, b) enhanced vertical mixing and dispersion of air person during summer time, c) the rain during monsoon might washout the aerosols and in addition to the dissolving of radon gas in precipitation and d) reduction in the emanation of radon from soil when the soil is saturated with water during monsoon season <sup>(12,16,18-22)</sup>. The detailed observation of radon progeny variations with meteorological parameters are tabulated in table 1.

The mean radon progeny concentration in the present study is higher compared to the results obtained in other regions <sup>(23)</sup> and presented in table 2. This may be because of the rocky terrains and trapping of air-masses near the observation site due to local topography.

**Table 1.** Monthly mean values of radon progeny and other meteorological parameters.

Month (of 2012)	Number of Samples	Radon progenies concentration (mWL)	Pressure (mbar)	Min Temp (°C)	Max Temp (°C)	Min RH (%)	Max RH (%)
February	1008	$7.82 \pm 0.36$	970	17.6	35.8	30.5	89.8
March	2304	$4.90 \pm 0.25$	969	22.0	38.7	24.7	91.6
April	1296	$3.11 \pm 0.15$	968	24.1	42.2	27.0	90.9
June	1728	$2.22 \pm 0.09$	945	25.6	38.0	37.5	78.7
July	1152	$0.71 \pm 0.03$	961	25.7	36.7	40.5	75.3
August	1872	$3.11 \pm 0.14$	958	24.3	37.8	41.5	85.0
September	1007	$5.77 \pm 0.26$	968	24.4	38.0	42.2	88.2
October	1008	$6.65 \pm 0.30$	971	22.8	35.5	49.8	91.8
November	864	$7.02 \pm 0.32$	972	19.4	36.0	43.2	92.3
December	1296	$6.33 \pm 0.21$	974	18.4	33.5	48.1	94.8
<b>Average</b>	<b>Total=13535</b>	<b><math>4.76 \pm 0.73</math></b>	<b>965</b>	<b>22.4</b>	<b>37.2</b>	<b>38.5</b>	<b>87.8</b>

**Table 2.** Mean radon progeny concentration in few parts of India.

Study Region	Radon Progeny Concentration (mWL)
Present Study	$4.76 \pm 0.73$
Mysore <sup>(18)</sup>	0.84
Pune <sup>(24)</sup>	0.99
Hyderabad <sup>(25)</sup>	0.9
Mysore (Indoor) <sup>(26)</sup>	1.29
Nilgiri Biosphere <sup>(27)</sup>	3.54
Pune <sup>(28)</sup>	0.84

## CONCLUSION

In the present study, the observed concentration of aerosol attached radon progenies is higher during early morning and night hours due to strong temperature inversions and lower in the afternoon hours due to increased vertical mixing of air particulates. Nocturnal accumulation of radon daughters and high concentrations during early morning hours confirms the strong influence of temperature and humidity on progeny concentrations. The concentration of radon progeny during winter is

higher than in rainy and summer seasons. These results serves as the baseline data for this region, provides useful information for the monitoring outdoor radon daughters' exposure to the public and to study the ionization processes in the lower atmosphere. The average concentration of radon progeny in the study region is little higher compare to the other locations in India and this may be due to the rocky terrains and trapping of air-masses near the observation site. More systematic study on radon in air, soil is needed to arrive at dose exposure to the public.

## ACKNOWLEDGEMENTS

*Authors are thankful to the Director, National Atmospheric Research Laboratory for the constant encouragement and extending all the facility to carry out the experiments at Gadanki. The financial support by the Indian Space Research Organization (ISRO), Government of India is duly acknowledged.*

**Conflict of interest:** Declared none.

## REFERENCES

1. Petrov AI, Petrova GG, Panchishkina IN (2009) Profiles of polar conductivities and or radon-222 concentration in the atmosphere by stable and labile stratification of surface layer. *Atmos Res*, **91**: 206–214.
2. Wilkening M (1990) Radon in the Environment. *Elsevier Science Publishers, Amsterdam, The Netherlands*, 1–137.
3. Ramachandran TV, Muraleedharan TS, Shaikh AN, Subbaramu MC (1990) Seasonal variation of indoor radon and its progeny concentration in a dwelling. *Atmos Env*, **24A**: 639–643.
4. Hoppel WA, Anderson RV, Willet JC (1986) Atmospheric electricity in the planetary boundary layer in the earth's electrical environment. National Academy Press, Washington DC, USA, 149-165.
5. Darby S, Hill D, Auvinen A, Barros-Dios J M, Baysson H, Bochicchio F, Deo H, Falk R, Forastiere F, Hakama M, Heid I, Kreienbrock L, Kreuzer M, Lagarde F, Makelainen I, Muirhead C, Oberaigner W, Pershagen G, Ruano-Ravina A, Ruosteenoja E, Schaffrath Rosario A, Tirmarche M, Tomasek L, Whitley E, Wichmann H E, Doll R (2005) Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. *Brit Med J*, **330**: 223–228.
6. Stephan G, Oestreicher U, Lehmann R (2005) Chromosome aberrations in peripheral lymphocytes of individuals living in dwellings with an increased level of indoor radon concentrations. *International Congress Series*, **1276**: 29–32.
7. UNSCEAR (1993) United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation, Report to the General Assembly, (United Nations, New York).
8. Sathish LA, Nagaraja K, Ramanna HC, Nagesh V, Sundareshan S (2009) Concentration of radon, thoron and their progeny levels in different types of floorings, walls, rooms and building materials. *Iran J Radiat Res*, **7(1)**: 1-9.
9. Sathish LA and Nagaraja K (2012) Indoor 222Rn and 220Rn variations: Evidence for Boyle's law. *Iran J Radiat Res*, **9(4)**: 231-236.
10. Prasad BSN, Nagaraja K, Chandrashekara MS, Paramesh L, Madhava MS (2005) Diurnal and seasonal variations of radioactivity and electrical conductivity near the surface for a continental location Mysore, India. *Atm Res*, **76**: 65–77.
11. Nagaraja Kamsali, Sathish LA (2013) Preliminary results of radon levels at Bangalore University, Bangalore, Solid State Nuclear Track Detectors and Applications, (NL Singh, ed), Narosa publishing House, New Delhi, India.
12. Porstendörfer J, Butterweck G, Reineking A (1991) Diurnal variation of the concentrations of radon and its short-lived daughters in the atmosphere near the ground. *Atmos Env*, **25**: 709-713.
13. Gadhavi H and Jayaraman A (2010) Absorbing aerosols: contribution of biomass burning and implications for radiative forcing. *Annal Geophys*, **28**: 103–111.
14. Sesana L, Caprioli E, Marcazzan GM (2003) Long period study of outdoor radon concentration in Milan and correlation between its temporal variations and dispersion properties of atmosphere. *J Env Radioact*, **65**: 147–160.
15. Israelsson S, Knudsen E, Ungethüm (1973) Simultaneous measurements of radon (222Rn) and thoron (220Rn) in the atmospheric surface layer. *Tellus*, **25**: 281-290.
16. Agnieszka P and Krzysztof K (2009) Outdoor radon (222Rn) concentration in urban and rural area (central Poland) in relation to meteorological parameters, The 7<sup>th</sup> International conference on urban climate, 29 June – 3 July, 2009, Yokohama, Japan.
17. Kant K, Rashmi, Sonkawade RG, Sharma GS, Chauhan RP, Chakarvarti SK (2009) Seasonal variation of radon, thoron and their progeny levels in dwellings of Haryana and Western Uttar Pradesh. *Iran J Rad Res*, **7(2)**: 79-84.
18. Nagaraja K, Prasad BSN, Chandrashekara MS, Paramesh L, Madhava MS, Sannappa J, Pawar SD, Murugavel P, Kamra AK (2003) Radon and its short-lived progeny: variations near the ground. *Rad Meas*, **36**: 413-417.
19. Sannappa J, Paramesh L, Venkataramaiah P (1999) Study of radon exhalation in soil and air concentrations at

- Mysore. *Ind J Pure App Phy*, **73**: 629-639.
20. Porstendörfer J (1994) Properties and behaviour of radon and thoron and their decay products in the air. *J Aer Sci*, **25**: 219-263.
  21. Nagaraja K, Sathish LA (2010) Outdoor Radon Exposure and Doses in Pune, India. *Int. J Phys App*, **2(3)**: 69-72.
  22. Sathish LA, Nagaraja K, Ramachandran TV (2013) Radon reduction factor: A new approach for mitigation, Solid State Nuclear Track Detectors and Applications. (NL Singh, ed) Narosa publishing House, New Delhi, India.
  23. UNSCEAR (2000), United Nations Scientific Committee on the Sources to effects assessment for radon in homes and workplaces, Report to the General Assembly, United Nations, New York.
  24. Nagaraja K, Prasad BSN, Chandrashekara MS, Paramesh L, Madhava MS (2006) Inhalation dose due to radon and its progeny at Pune, *Ind J Pure & App Phy*, **44**: 353-359.
  25. Sreenath Reddy M, Sreenivasa Reddy B, Gopal Reddy, Yadagiri Reddy P, Rama Reddy K (2003) Study of indoor radon and its progeny concentration levels in the surrounding area of Hyderabad, Andhra Pradesh, India. *Rad Mea*, **36**: 507-510.
  26. Sathish LA, Sannappa J, Paramesh L (2001) Studies on indoor radon/thoron and their progeny levels at Mysore city, Karnataka State, *Ind J of Pure & App Phy*, **39**: 738-745.
  27. Sivakumar R (2010) A study on radon and thoron progeny levels in dwellings in South India. *Iran J Radiat Res*, **8(3)**: 149-154.
  28. Nagaraja K and Sathish LA (2010) Outdoor radon exposure and doses in Pune, India. *Int J Phys App*, **3**: 69-72.

