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Diurnal and Monthly Variation of Indoor Radon and Thoron Progeny Concentrations at A Hillside Place of Northern India

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The natural radioactivity levels all over the world can create health problems due to the inhalation of radioactive aerosols. Radon and thoron progeny content of indoor air have major contribution to natural radiation dose. In the present study, simultaneous indoor measurements of radon and thoron progeny concentrations have been carried out over a period of four months at a low activity hilly area of northern Punjab, India to see their diurnal and monthly variations. The method used for this purpose is based on the defined solid angle absolute beta counting of radioactive aerosols sampled on a filter. The average values of equilibrium equivalent radon and thoron concentrations were 5.20 Bq m^{-3} and 0.235 Bq m^{-3}, respectively, over the period August to November 2003. Both, EECRn and EECTh show a negative correlation with temperature.

Key Words: *Radon progeny, thoron progeny, indoor air, beta counting.*

Introduction

Most of the natural radioactivity in air is due to radon isotopes (^{222}Rn, ^{220}Rn) and their progeny. ^{222}Rn (Radon) and ^{220}Rn (Thoron) are radioactive gases that are the members of the decay series of ^{238}U and ^{232}Th, respectively. Radon and thoron are produced via the decay of their respective immediate forerunners ^{226}Ra and ^{224}Ra present naturally in the earth's crust and migrate to the atmosphere with vertical gas-phase diffusion process, where they decay to produce their progeny. Monitoring of indoor radon and thoron progeny levels acquired significance all over the world from the public health point of view since 1980s. The inhalation of radon and thoron progeny has the major contribution to the natural radioactivity dose. Health effects attributed to their inhalation are lung cancer, skin cancer and kidney diseases!. Numerous worldwide studies[2-4] of radon and its progeny evidenced strong diurnal and seasonal variations of their concentrations in near-surface air. Representative concentration data and time trend studies of thoron and its progeny are very scarce in literature due to the difficulties of their measurements[4]. Consequently, in many cases the radioactivity level in atmosphere underestimated.

In the present work, radon progeny (^{214}Po, ^{214}Pb, ^{214}Bi) and thoron progeny (^{212}Pb, ^{212}Bi, ^{208}Tl) concentrations were measured simultaneously in indoor air. Results are presented here in terms of equilibrium equivalent radon concentration (EEC_{RN}) and equilibrium equivalent thoron concentration (EEC_{TH}) values. An analysis of their variations on the daily and monthly basis is given in this paper.

Measurements Site

Measurements were performed at a height of 1.4 m above the surface in a classroom of Sri Sai College of Engineering and Technology (SSCET), Badhani, Pathankot, situated at the uphill side of northern Punjab. Total, 169 measurements (morning, afternoon, evening) were carried out for four months from August to November 2003. The sampling time in morning, afternoon and evening was confined to 5:00-7:00, 12:00-14:00 and 18:00-20:00, respectively. All the four windows and a door of the room were kept open during the measurements as under normal living conditions, which caused high natural ventilation of the room.

The method used to determine radon progeny (218Po, 214Bi, 214Pb) and thoron progeny (212Pb, 212Bi, 208Tl) simultaneously in indoor air was based on the defined solid

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angle absolute beta counting (DSAABC) of radioactive aerosols sampled on a micro fiber filter[5].

Build up and decay of radioactive atoms in the filter during and after the sampling were described by using the Bateman differential equations[6]. Various correction factors involved in the evaluations of absolute detection efficiencies were obtained by computations, estimations and eliminations one by one[7]. For the present experimental setup, (β-counting efficiencies 0.183, 0.205, 0.094, 0.137 and 0.220 were obtained for 214Pb, 214Bi, 212Pb, 212Bi and 208Tl, respectively.

Results and discussion

The EECRn and EECTh were computed according to the following formulae[4,5]:

$$EEC_{Rn}=0.105a_1+0.516a_2+0.37a_3 \quad (1)$$

$$EEC_{Th}=0.913a_4+0.087a_5 \quad (2)$$

where a_1. a_2. a_3, a_4, and a_5 are the activity concentrations of 218pO, 214Pb, 214Bi, 212Pb, and 212Bi, respectively. In the present study, the indoor average values of EEC_{Rn} and EEC_{Th} were 5.20 Bq m,3 and 0.235 Bq m^{-3} all over the investigation period of four months. The detailed statistical data is shown in **Table 1**.

A trend of high EECRn and EECTh values early in the morning and low in the afternoon was observed all over the investigation period. The degree of these variations was found to depend upon the stack pressure difference across the wall8, ventilation rate and the variations in the outdoor air9. As room was highly ventilated, therefore, these variations in indoor air were mainly due to the variations in outdoor air. This trend has already been evidenced in IiteraturelO- 12.]n the morning before the reach of solar radiations, temperature is low near the earth's surface and a temperature inversion layer is formed, which obstructs the vertical thermoconvective movements of radon, thoron and their progeny, therefore, their concentrations increase near the surface. With sun rise, temperature increases near the surface as a consequence of which thermoconvective motion of radon, thoron and their progeny take place, hence their concentrations decrease. A negative correlation coefficient of -0.84 was observed between outdoor temperature and indoor EECRn' Although negative correlation coefficient of -0.75 between outdoor temperature and indoor EECTh was comparatively highly low" yet it is considerable. This temperature dependence of the atmospheric stability leads to the daily, monthly and seasonal variations.

In **Figs. 1 and 2**, seven days based data for EECRn and EECTh show daily variation for the month of August. **Figs. 3** and **4**, respectively, show the daily variations of EECRn and EECTh for seven days in the month of November.

Some unexpected results were obtained in the month of September, a month with high number of rainy days. Temperature was low due to cloudiness and rainfall but EECRn and EECTh values were not high as expected rather were low due to the fact that low temperature goes with the high radon concentration within one day, but the connection between the daily average temperature and radon concentration within one year may be more complicated. The effects of wind, rain, cloudiness and aerosol concentration are important in this respect. As shown in the **Table-2**, the average temperature in the month of September is significantly low as compared to the month of August but concentration values are comparatively same.

Table 1 : Statistical parameters for temperature, EEC_{RN} and EET_{TH} for Aug.-Nov. (2003)

Parameter	Temperature (°C)	EEC_{RN} (Bq m	EEC_{TH} Bq m)
Number of measurements	169	169	169
Minimum	8.1	0.98	0.030
Maximum	36.5	15.25	0.650
Average	24.9	5.20	0.235
Median	25.90	4.54	0.202
Geometric Mean	24.0	4.47	0.192
Standard deviation	6.3	2.92	0.145

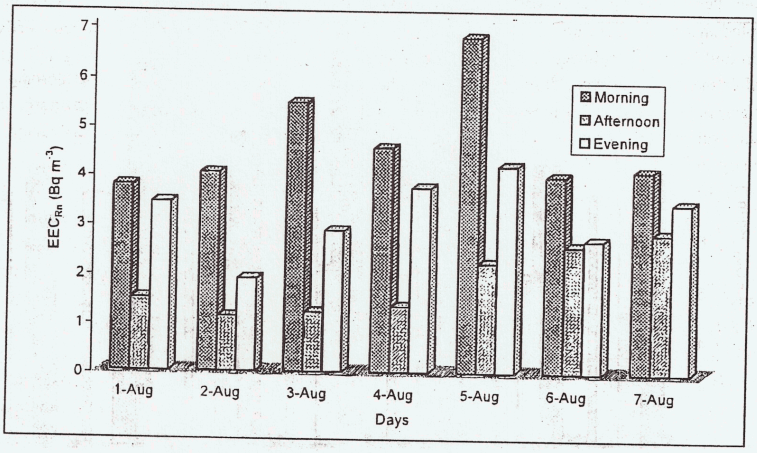

Fig. 1 : Diurnal variation of EEC_{Rn} in 7 non windy days of August.

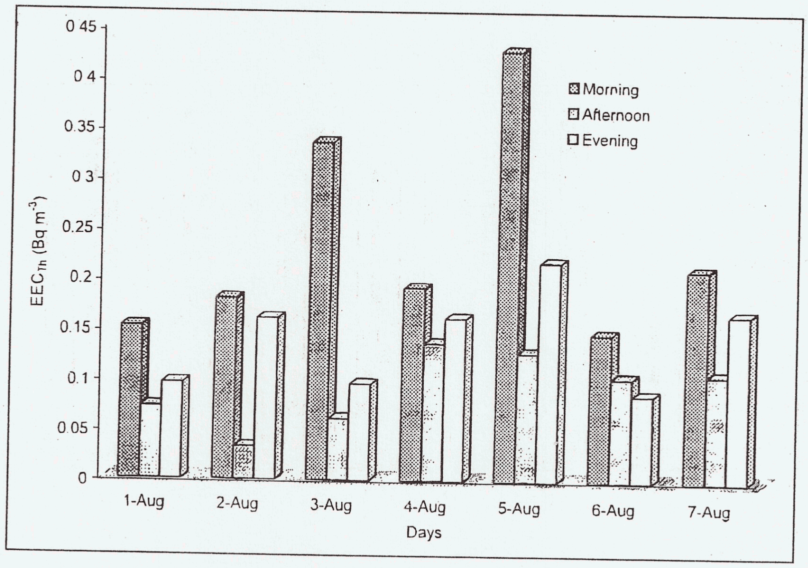

Fig. 2 : Diurnal variation of EEC_{Th} in 7 non windy days of August.

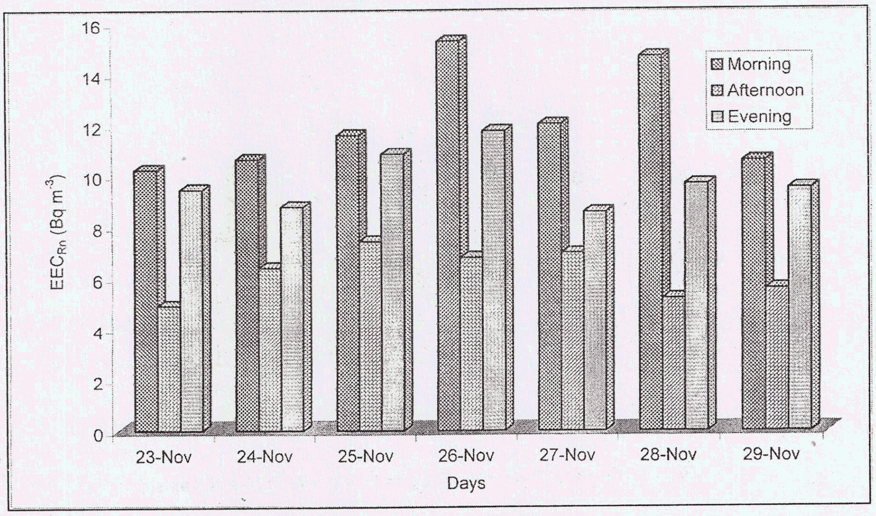

Fig. 3 : Diurnal variation of EEC_{Rn} in 7 non windy days of November.

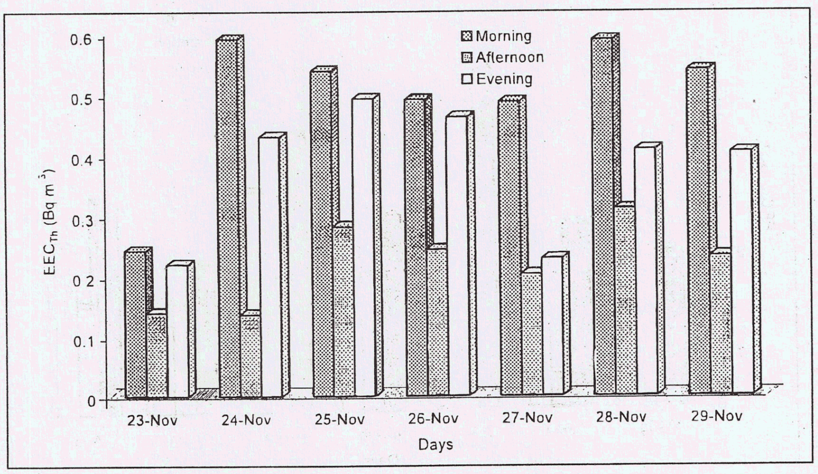

Fig. 4 : Diurnal variation of EEC_{Th} in 7 non windy days of November.

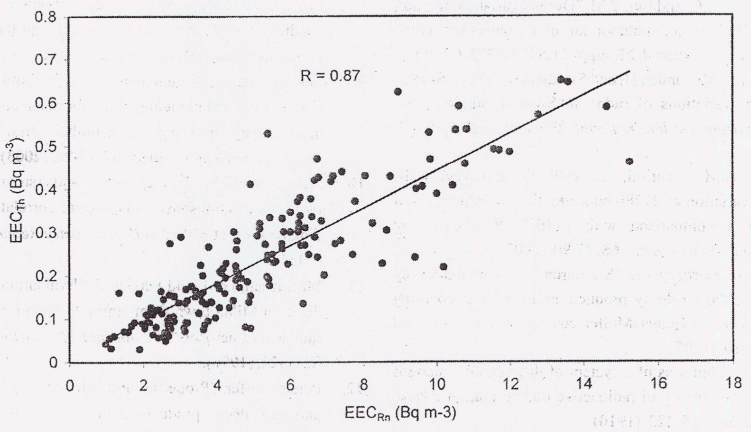

Fig. 5 : Corelation between EEC$_{Rn}$ and EEC$_{Th}$.

A possible cause of the decrease in the concentrations might be aerosol abatement due to the rain washout. Monthly average values of EECRn and EECTh are given in **Table 2.** A comparative study of EECRn and EECTh reveals that these have positive and approximately linear correlation with correlation coefficient of 0.87 as shown in the **Fig. 5.**

An effective equivalent dose indoor of 0.053 mSv y-1 due to the average EECTh of 0.235 Bq m-3 was calculated with conversion factor of 32 nSv/Bq.h.m-3 and an occupancy factor of 0.813. For EECRn with average value of 5.20 Bq m^{-3}, the effective equivalent dose calculated using the conversion factor of 9 nSv/Bq.h.m^{-3} and occupancy factor of 0.8 was 0.33 mSv y-1. Therefore, the contribution of EECTh is about 1.75% that of EECRn. The world average inhalation dose due to radon and its progeny is 1.2 mSv y-1 as recommended by UNSCEAR[9, 13].

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Table 2 : Monthly average data of temperature, EEC$_{RN}$ and EET$_{TH}$ and number of rainy days in a particular month.

Month	Number of Measurements	Temperature (°C)	Average EEC$_{RN}$ (Bq m	EEC$_{TH}$ Bq m)	Rainy Days
August	45	30.4	3.15	0.152	4
September	38	27.8	3.37	0.143	9
October	39	23.3	5.36	0.260	0

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