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Measurement of Indoor Radon and Thoron Levels in Some Districts of Punjab

H.S. Virk, N. Sharma, R.P. Singh and T.V. Ramachandran*

Guru Nanak Dev University, Department of Physics, Amritsar - 143 005

Results of indoor radon and thoron survey carried out in 5 districts of Punjab are reported. The survey estimated the annual geometric mean values for ^{222}Rn and ^{220}Rn concentrations to be 15.30 and 5.2 Bq/m^3, respectively. The equilibrium factors for radon and thoron in indoor environment are estimated to be 0.24 and 0.035, respectively. The average inhalation dose for local population in these districts is 0.18 μSv/h. Indoor concentration of radon shows seasonal variation with radon value for winter being almost double of that for summer. A similar variation is observed for thoron also. The observed values of concentrations and dose rates are well below the action levels prescribed by ICRP - 65 for protection against radiation.

INTRODUCTION

Radon (^{222}Rn) is a noble gas occurring as immediate decay product of radium (^{226}Ra) in decay series of uranium (^{238}U). As uranium is present in trace amounts almost everywhere in earth's crust and continuously decaying, so the radon is being continuously generated in earth's crust every where. Radon so generated is exhaled into free atmosphere via the processes of diffusion and convective flow of soil air. Considerably higher radon levels can occur if radon is released to confined air spaces, such as underground mines and houses. It is fairly well established that radon (^{222}Rn) and its progeny are the biggest single contributor to natural radiation exposure of general public. Also, the relation between the lung cancer and the exposure to radon and daughters is well known from several studies (Rajewsky, 1940; Sevc *et al.*, 1976; Edling *et al.*, 1986). From the recent surveys in many countries, it has been established that a significant part of this dose is contributed by an isotopic sister of radon, that is thoron, (^{220}Rn) and its progeny occurring in decay series of thorium (^{234}Th) (Steinhausler *et al.*, 1994).

In view of these facts, a survey is being carried out in Punjab under coordinated national project of Department of Atomic Energy (DAE), Govt. of India, to assess the indoor environment for exposure to Rn/Th and their progeny. This paper presents the results of a survey for the 5 districts of Punjab, namely Bathinda, Mansa, Patiala, Sangrur and Moga for which the survey has been carried out for a period of 1 year (March 1997 - March 1998).

EXPERIMENTAL TECHNIQUE

Track - etch technique using SSNTD is considered to be one of the best techniques available for passive integrated measurements (Frank and Benton, 1970). We have utilized this technique using 12 μm thick cellulose nitrate film commonly known as LR - 115 type II as detector in this survey. Details of this technique are available elsewhere (Prasad, 1994; Virk *et al.*, 1998).

In order to measure the concentration of radon and thoron separately, the detectors were exposed in twin chamber dosimeter cups obtained from Environment Assessment Division, BARC, Trombay. These cups have 2 chambers each with a height of 4.5 cm and diameter 6.2 cm. The detectors were fixed at the bottom of each chamber and the mouth of one chamber is covered with glass fibre filter paper and the other with a semi permeable membrane (NWSUR, 1994). These cups also have provision for exposing the detector in bare mode also on outer side of the cup. The detector in the chamber covered with membrane records alpha tracks due to radon (^{222}Rn) only as membrane allows only radon to pass through it and suppresses the thoron to less than 1 %. The other chamber detector, covered with filter paper records tracks due

*Bhabha Atomic Research Centre, Environment Assessment Division, Trombay, Mumbai - 400 085

Table 1. *Radon/thoron concentration levels and dose rates in dwellings of Punjab (March 1997 - March 1998)*

Season	Radon conc., Bq/m^3		Equilibrium factor for radon, FR		Thoron conc., Bq/m^3		Equilibrium factor for thoron, FT		Dose rate, $\mu Sv/h$	
	GM	GSD	GM	GSD	GM	GSD	GM	GSD	GM	GSD
Summer (Mar-Jun) (1997)	9.8	1.8	0.11	3.2	3.3	2.0	0.008	4.2	0.04	3.8
Monsoon (Jun-Sep) (1997)	11.6	1.8	0.16	3.6	4.2	2.3	0.015	5.8	0.08	4.8
Winter (Oct-Mar) (1997-98)	17.7	1.9	0.24	3.4	6.1	3.1	0.032	6.0	0.22	6.4
Annual avg.	15.3	1.6	0.24	1.9	5.2	2.4	0.035	3.1	0.18	4.0

to alpha particles from radon and thoron both. The Bare detector records the tracks due to alpha particles from radon, thoron and their progeny and is used to determine radon and thoron concentration in mWL. From this data the inhalation dose due to radon, thoron and their progeny can be calculated. These cups were exposed in 89 dwellings at a height of about 2.5 m from the ground. Exposure period of one year was covered in the form of 2, 3 month surveys and one 6 month survey. These exposed detectors were etched under standard conditions (2.5 N NaOH solution at 60 °C for 80 min) and counted for track density measurements using a spark - counter. Then using the calibration factors and the software developed at Bhabha Atomic Research Centre (BARC), Trombay, the track densities were converted to radon and thoron concentrations and other factors, that is dose, equilibrium factors and progency concentrations were calculated.

THEORETICAL FORMULATION

The methodology proposed by Mayya *et al.* (1998) for mixed field situations have been used to calculate the dose rates as well as equilibrium factors. Let T_1, T_2, T_3 be the track densities for membrane chamber film, filter paper chamber film and bare film, respectively. Let S_1 and S_1' be the calibration factors for the radon in membrane and filter compartments, respectively and S_2 be the calibration factor for thoron in filter compartment and d be the exposure period in days.

Then radon concentration $C_r = T_1 / (d . S_1)$ ...(1)

Thoron concentration $C_t = (T_2 - d . C_r . S_1') / (d . S_2)$ ...(2)

The activity fractions of the progeny are controlled by their wall loss rates for fine (λ^f_w) and coarse fraction (λ^c_w) and ventilation rates (λ_v) through the following formulae :

For radon progeny

$$F_{r-a} = \lambda_{r-a} / [\lambda_{r-a} + f_a \lambda^f_w + (1-f_a) \lambda^c_w + \lambda_v] \quad ...(3)$$

$$F_{r-b} = F_{r-a} \lambda_{r-b} / [\lambda_{r-b} + f_b \lambda^f_w + (1 - f_b) \lambda^c_w + \lambda_v] \quad ...(4)$$

$$F_{r-c} = F_{r-b} \lambda_{r-c} / [\lambda_{r-c} + f_c \lambda^f_w + (1- f_c) \lambda^c_w + \lambda_v] \quad ...(5)$$

where f_a, f_b, f_c are the unattached fractions for the respective species.

And for thoron progeny :

$$F_{t-b} = \lambda_{t-b} / (\lambda_{t-b} + \lambda^c_w + \lambda_v) \quad ...(6)$$

$$F_{t-c} = F_{t-b} \lambda_{t-c} / (\lambda_{t-c} + \lambda^c_w + \lambda_v) \quad ...(7)$$

assuming that thoron progeny unattached fractions ere negligible.

The bare track density T_3 is related to the concentration of both the gases and their daughters through equation :

$$T_3 = S_3 . d [\{ C_r + C_{r-a} + C_{r-c} \} + \{ 2C_t + C_{t-c} \}] \quad ...(8)$$

where S_3 is the calibration factor for the bare film, C_{r-a} and C_{r-c} are the concentrations of the radon daughters ^{218}Po and ^{214}Po, respectively and C'_{t-c} is the concentration of the thoron daughter ^{212}Po. The bare track density is dependant on the ventilation rate through equations for progeny fractions for both the gases. Considering the one dimensional spatial profile for thoron, ventilation parameter is worked out using equation 8. The progeny wor-

Table 2. *Radon/thoron progeny levels (March 1997 - March 1998)*

Season	Radon progeny conc., mWL		Thoron progeny conc., mWL	
	GM	GSD	GM	GSD
Summar (Mar-Jun) (1997)	0.38	2.35	1.61	9 21
Monsoon (Jun-Sep) (1997)	0.64	2.87	6.96	9.44
Winter (Oct-Mar) (1997-98)	1.15	3.16	15.39	16 76
Annual avg.	0.94	2.27	11.32	8.85

king levels are determined using equations :

$$WL_r = C_r . F_r/3700 = C_r (0.104 F_{r-a} + 0.518 F_{r-b} + 0.37 F_{r-c})/3700 \quad ...(9)$$

$$WL_t = C'_t . F_t/275 = C'_t (0.908 F_{t-b} + 0.092 F_{t-c})/275 \quad ... (10)$$

Where C'T is the room averaged thoron concentration calculated, taking into account the spatial profile of thoron. The dose rate is calculated by UNSCEAR (1993) formula :

$$D (\mu Sv/h) = 10^{-3} [(0.17 + 9F_r) C_r + (0.11 + 32F_t) C'T] \quad ... (11)$$

A computer programme has been developed at BARC to carry out these calculations and we have used the following typical values for various parameters :

$f_a = 0.2, f_b = 0.025, f_c = 0.001 \ \lambda^t_w = 10h^{-1}, \lambda^r_w = 0.1 \ h^{-1}$

RESULT AND DISCUSSION

Yearly averaged indoor radon and thoron concentration in 89 dwellings are summarized in the table 1. The Davies test for logarthmic distribution shows that the collected data is logarithmic, so geometric mean (GM) is the best average for this type of data set. Indoor radon concentration varies from a minimum value of 6.4 Bq/m^3 to a maximum value of 59.1 Bq/m^3 with annual geometric mean conc. of radon as 15.3 Bq/m^3 and a GSD value of 1.6. The GM of radon for winter season (Oct. 1997 - Mar. 1998) is 17.7 Bq/m^3 while for summer (Mar. 1997 - June 1997), it is 9.8 Bq/m^3. Obviously, a difference of factor 2 in the winter and summer radon conc. is attributable to reduced ventilation and increased exhalation in winter. The GM value of radon for rainy season (Jun. 1997 - Sep. 1997) is 11.6 Bq/m^3 with a GSD value of 1.8. As obvious from table 1, the radon value for rainy season is about 18 % higher than the value for summer season. It is due to the reason that because of wetting of soil adjacent to a house, the escape of radon from soil outside the house is blocked due to capping effect, and radon in soil finds an easy way out from the comparatively dry soil of the house. Similar seasonal variations were observed by the workers.

The indoor thoron concentration varies from 0.2 to 26.4 Bq/m^3 with an annual geometric mean value of 5.2 Bq/m^3 and a GSD value of 2.4. The GM value for winter season is 6.1 Bq/m^3 while for summer it is 3.3 Bq/m^3. As in the case of radon, thoron value for winter is also almost double than the summer value. The progeny concentrations of both radon and thoron are summarised in table 2. The radon progeny concentration varies from a minimum value of 0.1 mWL to a maximum of 4.8 mWL with yearly average geometric mean value of 0.94 mWL. The progeny concentration for thoron varies from 0.1 to 175.2 mWL with yearly average geometric mean value of 11.32 mWL.

Equilibrium factors of radon and thoron for indoor environment of Punjab dwellings are found to be 0.24 and 0.035, respectively with GSD, values of 1.9 and 3.1, respectively; the equilibrium factors are maximum for winter season, obviously due to ventilation effect. The computed dose rate varies from 0.04μSv/h in summer to 0.22μSv/h for winter with an annual GM value of 0.18μSv/h. International Commission on Radiological Protection (ICRP) in its publication number 65 has recommended that some remedial measure against radon in dwellings is always justified above a continued effective dose of 10mSv (ICRP, 1994). ICRP recommends an action level in the range of about 3 - 10 mSv/y corresponding to radon concentration in the range 200 - 600 Bq/m^3. In the light of these facts it can be seen that values of radon concentrations and dose rates as reported for Punjab dwellings are well below the action levels. We may conclude that radon exposure is not a significant health hazard in these districts.

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AUTHOR

1. Dr. H.S. Virk, Professor, Department of Physics, Guru Nanak Dev University, Amritsar - 143 005

2. Sri Navjeet Sharma, Research Scholar, Department of Physics, Guru Nanak Dev University, Amritsar - 143 005

3. Sri R.P. Singh, Research Scholar, Department of Physics, Guru Nanak Dev University, Amritsar - 143 005

4*. Dr. T.V. Ramachandran, Scientific Officer (E), Environmental Assessment Divison, Bhabha Atomic Research Centre, Trombay, Mumbai - 400 085

KEYWORDRS

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