INDOOR LEVELS OF RADON /THORON IN SOME DWELLINGS OF PUNJAB AND HIMACHAL PRADESH, INDIA.

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1. 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, i.e. thoron (^{220}Rn) and its progeny occurring in decay series of thorium (^{232}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 of the few districts of Punjab and Himachal Pradesh for which the survey has been carried out for a period of one year.

1.1 Experimental Technique

Track-etch technique using SSNTD is considered to be one of the best techniques available for passive integrated measurements (Frank & Benton, 1970). We have utilized this technique using 12μm thick cellulose nitrate film commonly known as LR-115 Type II as detector and twin chamber dosemeter cups as per standard protocol of DAE. Details of this technique are available elsewhere (Prasad, 1994;Virk et al.1998).

The detectors were exposed in twin chamber dosimeter cups obtained from Environment Assessment Division, BARC, Trombay. These cups have two 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 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. The other chamber detector, covered with filter paper records tracks due to alpha particles from radon and thoron both. Bare detector records 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. The cups were exposed in 90 dwellings in five districts of Punjab and 29 dwellings in two districts of Himachal Pradesh. These cups were exposed at a height of about 2.5m from the ground. Exposure period of one year was covered in the form of two, three month surveys and one six month survey. Measurements were made in Punjab districts from March 1997 to March 1998 while for Himachal Pradesh the measurement period was August 1997 to September 1998. These exposed detectors were etched under standard conditions (2.5N 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

BARC, Trombay the track densities were converted to radon and thoron concentrations and other factors, i.e., dose rate, equilibrium factors and progeny concentrations were calculated. 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, i.e.,dose, equilibrium factors and progeny concentrations were calculated.

1.2 Theoretical formulation

The methodology proposed by Mayya et al. (1998) for mixed field situations have been used to calculate the dose rate 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 $C_R = T_1/(d \cdot S_1)$ and (1)

thoron concentration $C_T = (T_2 - d \cdot C_R \cdot S_1^{/}) / (d \cdot S_2)$ (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 are 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 working 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 :

$f_A = 0.2$, $f_B = 0.025$, $f_C = 0.001$, $\lambda^f_W = 10\ h^{-1}$, $\lambda^c_W = 0.1\ h^{-1}$.

1.3 Results and Discussion

The collected data shows logarithmic distribution, so Geometric Mean (G.M.) is the best average for this type of data set. Yearly averaged indoor radon and thoron concentrations in 90 dwellings of Punjab are summarized in the table 1. 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 G.S.D.value of 1.6. The G.M. 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 two in the winter and summer radon conc. is attributable to reduced ventilation and increased exhalation in winter. The G.M. value of radon for rainy season (Jun.1997-Sep.1997) is 11.6 Bq/m^3 with a G.S.D. value of 1.8 . As obvious from table 1 ,the radon value for rainy season is about 18 percent 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.

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

	Radon Conc. (Bq/m^3)		Equilibrium Factor for Radon (FR)		Thoron Conc. (Bq/m^3)		Equilibrium factor for Thoron FT		Dose Rate (μSv/h)	
Season	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D
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.	5.3	1.6	0.24	1.9	5.2	2.4	0.035	3.1	0.18	4.0

The indoor thoron concentration varies from 0.2 Bq/m^3 to 26.4 Bq/m^3 with an annual geometric mean value of 5.2 Bq/m^3 and a G.S.D. value of 2.4 .The G.M. 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 mWL to 175.2 mWL with yearly average geometric mean value of 11.32 mWL. Equilibrium factors for radon and thoron for indoor environment of Punjab dwellings are found to be 0.24 and 0.035 respectively with G.S.D. 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 G.M. value of 0.18μSv/h.

Table 2. Radon/Thoron concentration levels and dose rates in dwellings of Punjab, India (March 1997-March 1998)

	Radon Conc. (Bq/m^3)		Equilibrium Factor for Radon (FR)		Thoron Conc. (Bq/m^3)		Equilibrium factor for Thoron FT		Dose Rate (μSv/h)	
Season	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D	G.M	G.S.D
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.	5.3	1.6	0.24	1.9	5.2	2.4	0.035	3.1	0.18	4.0

Yearly average indoor radon/thoron concentrations in 29 dwellings of Himachal Pradesh are summarised in table 3. Indoor radon concentration varies from a minimum of 19.7 Bq/m^3 to a maximum of 146.3 Bq/m^3 with annual geometric mean concentration of 48.4 Bq/m^3 and a G.S.D. Value of 1.7. The G.M. of radon for winter season (Dec.1997-Mar.1998) is 68.7 Bq/m^3 while for period Apr.1998-Sep. 1998, it is 36.5 Bq/m^3. The G.M. value of radon for Aug.1997-Nov.1997 is 45.5 Bq/m^3 with a G.S.D. value of 1.7 . The indoor thoron concentration varies from 9.1 Bq/m^3 to 70.7 Bq/m^3 with an annual geometric mean value of 21.7 Bq/m^3 and a G.S.D. value of 1.8. The G.M. value for winter season is 30.7 Bq/m^3 while for period Apr.1998-Sep. 1998, it is 12.4 Bq/m^3 . The progeny concentrations of both radon and thoron are summarised in table 4. The radon progeny concentration varies from a minimum value of 0.83 mWL to a maximum of 16.47 mWL with yearly average geometric mean value of 5.0 mWL. The progeny concentration for thoron has yearly average geometric mean value of 183.3 mWL. Equilibrium factors for radon and thoron for indoor environment of Himachal Pradesh dwellings are found to be 0.36 and 0.062 respectively with G.S.D. values of 1.6 and 2.0 respectively . The dose rate has yearly G.M value 1.9 μSv/h.

Table 3. Radon/Thoron concentration levels and dose rates in dwellings of Himachal Pradesh, India (August,1997- September,1998)

	Radon Conc. (Bq/m^3)		Equilibrium Factor for Radon (FR)		Thoron Conc. (Bq/m^3)		Equilibrium Factor for Thoron (FT)		Dose Rate (μSv/h)	
Season	G.M.	G.S.D.	G.M.	G.S.D.	G.M.	G.S.D.	G.M.	G.S.D.	G.M.	G.S.D.
(Aug.-Nov.) (1997)	45.5	1.7	0.260	3.2	22.4	2.3	0.034	5.2	0.83	5.1
(Dec.-Mar.) (1997-98)	8.7	1.8	0.474	1.4	30.7	2.2	0.083	2.2	3.67	3.2
(Apr.-Sep.) (1998)	6.5	1.8	0.209	3.3	12.4	2.4	0.023	5.4	0.34	7.0
Annual Avg.	48.4	1.7	0.358	1.6	21.7	1.8	0.062	2.0	1.9	2.2

Table 4. Radon / Thoron progeny levels in dwellings of Himachal Pradesh, India (Aug. 1997-Sep. 1998)

	Radon Progeny Conc. (mWL)		Thoron Progeny Conc. (mWL)	
Season	G.M.	G.S.D.	G.M.	G.S.D.
(Aug.-Nov.) (1997)	3.21	2.9	46.2	15.2
(Dec.-Mar.) (1997-98)	8.73	2.0	341.81	4.0
(Apr.-Sep.) (1998)	2.4	3.0	15.3	22.4
Annual Avg.	5.0	1.7	183.3	2.5

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