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Measurement of Indoor Radon and Thoron using Single entry Pin-Hole Dosimeters in the dwellings of Bathinda District of Punjab, India

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Abstract— **An indoor radon and thoron study has been carried out in 24 dwellings 0f 8 villages situated in Bathinda district of Punjab, using LR-115 type II nuclear track detectors installed for three months in four seasons covering a period of one year. Indoor radon values varied from 7.20 to 47.39 Bqm^{-3} in rainy, 38.24 to 59.80 Bq m^{-3} in winter, 9.64 to 63.07 Bq m^{-3} in spring and 2.61 to 79.08 Bqm^{-3} in summer time with an average values of 30.70, 49.44, 30.97 and 21.80 Bq m^{-3} respectively. Indoor thoron concentrations varied from 31.11 to 150.51Bq m^{-3} in rainy, 76.67 to 177.22Bq m^{-3} in winter, 7.22 to 197.78 Bq m^{-3} in spring and 34.44 to 217.78 Bq m^{-3} in summer time with an average values were found to be 78.73, 120, 101.85 and 86.49 Bq m^{-3} in the corresponding seasons. The average annual effective dose to the residents in dwellings for radon and thoron is 0.96 and 2.44 mSv y^{-1} respectively.**

Index Terms — **Annual Effective dose, Nuclear track detectors, Radon, seasonal variations, Thoron.**

INTRODUCTION

Radon possess three naturally occurring radioactive isotopes namely ^{220}Rn (Thoron), with half-life of 55.6s, ^{219}Rn (Actinon) with half-life of 3.96s and ^{222}Rn with half-life of 3.8 days [1]. As short lived ^{219}Rn has low activity in the environs, only ^{220}Rn and ^{222}Rn shows their presence in indoors. The World Health Organization [2] recognized radon exposure as the second major cause for lung cancer, after smoking. Radon and thoron originates from uranium (^{238}U) and thorium (^{232}Th) respectively, which is present in the earth's crust in variable concentrations [3]. The estimated world average of annual effective dose to the human beings by natural radiation is 2.4 mSv/y and about 50% of which is due to internal exposure of radon and thoron progenies [4]. This grasps the essence of extensive radon measuring campaigns and epidemiological studies made in the previous decades [5]. Radon oozes out from the earth's surface through its production point, where it resides in the environs including our homes, offices and other workplaces especially in the buildings having uncovered floors (mud floorings). Along with radon, thoron also plays a vital role in the risk evaluation [6]. As radon is a gas, its decay products form a very fine dust, which is toxic and radioactive in nature. It may potentially stick to the sensitive lung tissues by inhalation and do heavy damage than radon itself [7]. Various studies revealed that occupationally radon exposed miners and direct observation from the individuals exposed to indoor radon in their houses provide a firm scientific foundation which proves that radon is a major environmental carcinogen [8][9][10][11]. Previous studies done all over the world shows that systematic and well planned measurements of indoor radon and thoron concentration are necessary to calculate the actual levels and effective dose due to exposure of indoor radon and thoron. In the last years the interest to thoron (^{220}Rn) is also increasing [12] [13]. The present study is aimed to measure the radon and

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thoron concentration and annual effective dose in the selected dwellings of 8 villages of District thoron levels with different building construction materials and ventilation conditions of the rooms of all dwellings.

GEOGRAPHY OF STUDY AREA

The selected area Bathinda is a district of Punjab state which is situated in the northwestern region of India. The exact co-ordinates of Bathinda are 30.20°N 74.95°E with an average elevation of 201 meters from the sea level. Its climate corresponds to high variation between summer and winter temperatures.

BUILDING CHARACTERSTICS

For radon and thoron measurements, one room in each of the 24 dwellings was randomly selected from the type of living room, kitchen, bedroom etc. All the selected dwellings were constructed using cement, concrete, marble and bricks. Most of the dwellings were partially ventilated and had single storey. During summer ceiling fans were used in most of the rooms and only few used air conditioners and air coolers.

MATERIALS AND METHODS

Single entry pin-hole based detector was used to measure the concentration of radon and thoron in the indoor environment. The detector has two identical cylindrical chambers each having length of 4.1 cm and radius 3.1 cm and are separated by a pinhole based ^{222}Rn/^{220}Rn discriminating plate. Radon and thoron enter the first chamber, called “radon + thoron” chamber, through a filter paper which filters out the decay products of radon and thoron. However, only radon diffuses into the Bathinda, Punjab. An attempt has been made to find possible relationships of indoor radon and second chamber, called “radon” chamber, through four pin-holes of discriminating plate which cut off thoron due to its short half-life. Therefore, the LR-115 film kept in the ‘radon + thoron’ chamber registers the alpha tracks due to both radon and thoron and their progeny, while the LR-115 film in the ‘radon’ chamber registers the alpha tracks only due to ^{222}Rn and its progeny. The use of multiple pin-holes of reasonably small radius minimizes the effect of turbulence on ^{222}Rn/^{220}Rn transmission factors so that the calibration factor remains independent of indoor turbulence [14].

These detectors, keeping LR-115 Type-II films of size 3×3 cm, were suspended in the selected rooms at a height >200 cm above the ground level (so that the detectors remain undisturbed by the random movement of the residents) and about 50-60 cm below the ceiling of the room. The detectors were mounted along the corner of the room about 80 cm away from the two adjacent walls. After the completion of exposure period of 90 days, films were removed from the both chambers and etched using 2.5 N NaOH solution at 60^0C for 90 minutes. After this chemical treatment, the etched films were thoroughly washed and dried. The registered tracks were counted using spark counter. Average concentrations of radon and thoron were calculated by using the following equations [14]

$$K_{R,1} = \frac{T_{R,1} - B}{tC_R} \qquad (1)$$

$$K_{T,1} = \frac{T_{T,1} - B}{tC_T} \qquad (2)$$

Here $K_{R,1}$, $K_{T,1}$ are the calibration factors, $K_{R,1}$ = 0.017 tr. cm^{-2} (Bq m^{-3} d)$^{-1}$ in 'radon' chamber, $K_{T,1}$ = 0.01 tr. cm^{-2} (Bq m^{-3} d)$^{-1}$ in 'radon + thoron' chamber, $T_{R,1}$ is total track density (tr. cm^{-2}) in detectors for radon in 'radon' chamber, $T_{T,1}$ is track density (tr. cm^{-2}) of thoron in 'radon + thoron' chamber, B is the background track density for unexposed LR-115 films (about 4 ± 2 tr. cm^{-2}). C_R and C_T is the entry face concentration (Bqm^{-3}) of radon and thoron and t is exposure period [14].

The annual effective dose due to the exposure to radon, thoron and their progeny in the dwellings of study area were calculated using the following relations [4]:

Annual effective dose from radon and its progeny = C_R (Bq m^{-3}) × 0.46× 7000h × 9 n Sv (Bq h m^{-3})$^{-1}$

Annual effective dose from thoron and its progeny = C_T (Bq m^{-3}) × 0.09× 7000h × 40 n Sv (Bq h m^{-3})$^{-1}$

RESULTS AND DISCUSSION

The seasonal variations of radon and thoron concentrations for 24 dwellings of 8 villages (Three in each village) are summarized in Table 1. The radon concentration varied from 7.20 to 47.39 Bqm^{-3} in rainy, 38.24 to 59.80 Bq m^{-3} in winter, 9.64 to 63.07 Bq m^{-3} in spring and 2.61 to 79.08 Bqm^{-3} in summer time. The average values over all the 8 villages (24 dwellings) for the corresponding seasons were found to be 30.70, 49.44, 30.97 and 21.80 Bq m^{-3} respectively. Thoron concentration varied from 31.11 to 150.51Bq m^{-3} in rainy, 76.67 to 177.22 Bq m^{-3} in winter, 7.22 to 197.78 Bq m^{-3} in spring and 34.44 to 217.78 Bq m^{-3} in summer time and the average values were found to be 78.73, 120, 101.85 and 86.49 Bq m^{-3} respectively. It can be seen that radon and thoron concentrations for most of the dwellings are higher in winter than in summer. This is because of escape of radon and thoron due to high ventilation conditions (opened doors and windows) in dwellings and use of electrical appliances like fan, cooler and air conditioner in summer. In winter, the ventilation conditions were poor, as doors and windows remained closed and electrical appliances were turned off for all the time. The annual average concentration of radon over all the seasons and all the 8 villages is obtained as 33.23 Bqm^{-3}, which is less than the lower limit of the action level (200-300 Bq m^{-3}) recommended by International Commission on Radiological Protection [15]. It is also lower than that of the world average value of 40 Bqm^{-3}[4] and the action level (100 Bqm^{-3}) recommended by World Health Organization [16]. The average annual effective dose of radon and thoron is found to be 0.96 and 2.44 mSv respectively. In all the villages, the annual effective dose received by the occupants is less than the lower limit of the recommended action level 3-10 mSv y^{-1} (ICRP, 1993) [17].

Table 1 Seasonal variation of concentration of radon and thoron and corresponding average annual effective dose.

	Aug-Nov(2014)		Nov(2014)-Feb(2015)		Feb-May(2015)		May-Aug(2015)		Annual effective Dose of Radon (mSv)	Annual effective Dose of Thoron (mSv)
Village Name	**Rainy**		**Winter**		**Spring**		**Summer**			
	C_R Bq m^{-3}	C_T Bq m^{-3}	C_R Bqm^{-3}	C_T Bq m^{-3}	C_R Bqm^{-3}	C_T Bq m^{-3}	C_R Bq m^{-3}	C_T Bq m^{-3}		
Burj Sema	26.11	78.06	40.52	120.00	27.45	60.28	15.36	34.44	0.79	1.84
	39.17	130.61	55.56	109.44	17.97	38.89	19.61	55.56	0.96	2.11
	31.81	134.95	41.99	102.22	46.73	109.17	8.99	53.61	0.94	2.52
Chathewala	22.66	55.36	55.23	107.78	55.39	165.00	79.08	214.44	1.54	3.42
	20.26	49.49	46.73	76.67	28.76	67.78	9.15	217.78	0.76	2.59
	24.31	73.21	38.24	106.67	30.07	133.89	2.61	82.22	0.69	2.49
Kaureana	20.11	60.97	59.80	117.22	33.01	82.22	5.56	41.67	0.86	1.90
	36.46	70.41	51.96	92.22	18.95	74.44	30.07	64.44	1.00	1.90
	7.20	52.55	42.81	98.89	28.10	77.78	12.75	53.33	0.66	1.78
Mirjeana	26.41	47.45	53.92	94.44	19.61	56.39	9.80	103.33	0.80	1.90
	40.82	92.35	42.16	94.44	21.24	152.50	60.13	126.11	1.19	2.93
	30.76	60.71	48.69	118.33	22.55	73.33	32.35	84.44	0.97	2.12
Manuana	33.01	92.86	55.56	135.00	9.64	7.22	29.41	117.78	0.92	2.22
	39.02	80.10	59.48	145.56	17.16	192.78	11.44	60.56	0.92	3.02
	36.46	150.51	48.37	119.44	30.39	63.61	27.45	105.11	1.03	2.76
Maurchart	34.16	80.11	47.06	94.44	37.91	119.17	15.36	85.56	0.97	2.39
	22.84	64.89	52.29	145.56	23.69	84.17	3.59	61.11	0.74	2.24
	43.33	84.41	40.20	90.56	63.07	174.44	6.54	68.89	1.11	2.64
Burj	38.49	97.07	42.65	112.78	44.28	197.78	10.46	55.56	0.98	4.18
	28.16	70.74	46.41	170.56	28.43	163.33	16.34	58.89	0.86	2.92
	27.53	85.37	57.84	177.22	32.03	87.22	27.12	82.22	1.05	2.72
Gatwali	23.86	75.56	52.61	137.22	57.19	136.39	20.59	52.22	1.12	2.53
	47.39	31.11	55.88	159.67	18.30	62.78	39.87	86.67	1.17	2.14
	36.44	70.56	50.65	155.00	31.37	63.89	29.58	110	1.07	2.52
Average	30.70	78.73	49.44	120	30.97	101.85	21.80	86.49	0.96	2.44

Table 2 The Building construction materials, ventilation conditions in 48 dwellings of 12 villages.

Sample location	**Dwelling 1**		**Dwelling 2**		**Dwelling 3**	
BATHINDA Distt.	Type	V.C	Type	V.C	Type	V.C
Burj Sema	H2	II	H2	II	H2	I
Chathewala	H3	II	H4	II	H4	III
Kaureana	H2	II	H1	II	H4	III
Mirjeana	H5	III	H4	II	H2	I
Manuana	H4	II	H2	I	H2	II
Maurchart	H4	I	H5	II	H1	II
Burj	H1	I	H1	I	H1	I
Gatwali	H4	I	H1	II	H1	I

V.C : ventilation condition I: poorly ventilated, II: partially ventilated, III: well ventilated

H1: (Floor: Brick, Roof: Brick) H2: (Floor: concrete, Roof: bricks & white wash)
H3: (Floor: concrete, Roof: concrete) H4: (Floor: marble, Roof: Brick & POP)
H5: (Floor: Tile , Roof: bricks)

Table 2 shows the building construction materials and the ventilation conditions for all the 24 dwellings. The radon and thoron concentration levels in well-ventilated dwellings are lower as compared to poorly ventilated dwellings. This is because radon and thoron can easily escape out of the well-ventilated dwellings. Here a dwelling with one door and no window is considered as poorly ventilated, with one door and one window is partially ventilated and with more than one door and window as well ventilated.

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