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Analysis of Concentration of Radioactive Radon, Thoron and their Progeny in dwelling of Shahjahanpur District, Uttar Pradesh, India in different seasons

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ABSTRACT
The concentration of radioactive element, radon, Thoron and their progeny vary according to seasons in outdoor as well as in indoor areas. In the present study, solid state nuclear track detector was used to measure the concentration of radon ,thoron and their progeny in the residential houses of Shahjahanpur district of Uttar Pradesh, India and their concentration were recorded in four quarterly cycles in different seasons of the year. It has been observed that the indoor Concentration of radon varied from 9.00 Bq/m³ to 73.00 Bq/m³ with an average of 37.78 Bq/m³ and geometric mean 37.55 Bq/m³ with SD 4.19 Bq/m³ But we observe that the concentration of its progeny varied from 4.47 Bq/m³ to 27.21 Bq/m³ with an average of 20.27 Bq/m³ and geometric mean 14.26 Bq/m³ with SD 1.46 Bq/m³ It has been observed that the indoor Concentration of Thoron varied from 8.00 Bq/m³ to 38.00 Bq/m³ with an average of 21.49 Bq/m³ and geometric mean 21.22 Bq/m³ with SD 3.25 Bq/m³ But we observe that the concentration of its progeny varied from 0.69 Bq/m³ to 1.05 Bq/m³ with an average of 0.91 Bq/m³ and geometric mean 0.90 Bq/m³ with SD 0.11 Bq/m³.In the studied area, it has been found that the average value of concentration of Radon, Thoron and their progeny has been found minimum in the summer and in winter it is maximum.
Keywords :Equilibrium equivalent concentration of radon, equilibrium equivalent concentration of thoron, pinhole dosimeter, radon, solid-state nuclear track detector, thoron

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INTRODUCTION
Radioactive radon is an odorless and colorless gas which is obtained from the uranium by the natural radioactive decay. Radioactivity is a spontaneous and stochastic process that exhibited by several heavy elements present in nature. There are three main naturally occurring radioactive series namely Uranium-238, Thorium-232 and Uranium-235 series. These series are called the 4n, 4n+2, 4n+3 series respectively. One member of each series is a rare gas, being an isotope of radon(Rn-222, Rn-220 and Rn-219 respectively).Uranium is present in all type of rocks although its amount is small found between 1 and 3 PPM. Generally the uranium content in the soil is almost the same as in rocks from which it was derived. The amount of uranium in the soil depends on the local geology[1]. However the mobility of being a gas is much more than radium and uranium as they are present in the solid form in the soils and rocks. Radon can easily leave the soil and rocks by simple escaping into the pore spaces between the grains of soil and into opening and cracks in the rocks[2,3].
The quantity of radon and Thoron that enters a home depends on the efficiency and ease with which it moves in cracks or pore spaces. If they are able to move freely in stoma space, they can travel a great distance before decaying and is more likely to collect in high concentration inside the buildings[4,5].The primary route from which human get exposure to Radon and Thoron are inhalation from the infiltration of soil vapour into dwellings and buildings. The indoor Radon and Thoron concentration can also originate from water usage, outside air intrusion and the usage of construction materials which contain radium [EPA2003]. The foremost source of inhalation exposure is radon and Thoron gases that are released from the soil into an indoor surrounding and transferred in indoor air. Background degrees of Radon and Thoron in outdoor air is usually quite low and constitute a goal for decreasing indoor ranges. But their levels can range based on region and soil geology. In indoor places including houses, colleges and office buildings levels of Radon, Thoron and their progeny are usually higher than that of outdoor

places [6,7]. It is true that in newly constructed buildings, the indoor radon levels are high because of decrease in air entry or exit. Radon, released from ground water also increases its levels.
Radon and Thoron release ionizing radiation and proven carcinogens. The only effect that is known for Radon exposure to human health is lung cancer [8,9,10].The USEPA has anticipated that about 21000 lung cancer deaths every year in the U.S, are radon related. As cited above exposure to Radon and Thoron is the second leading cause of lung cancer after smoking[11,12,13].. In the prevailing study the measurement of the concentration of indoor Radon and Thoron and its progeny has been carried out in Shajahanpur district of central Uttar Pradesh, using a pin hole-based Radon /Thoron discriminating dosimeter and DTPS/DRPS(Direct Radon and Thoron progeny sensors)technique.

GEOLOGY OF STUDYAREA

The area of the present study is Shahjahanpur in Uttar Pradesh, India. Shahjahanpur district comes under mid- western plane zone of U.P. falling between the Himalayas on the north and the Gangetic plains in the south. The altitude of this region varies between 150-300 m. The soils are mostly alluvial and have developed on alluvium deposited of the Ganga and its tributaries. Soils are neutral to moderately alkaline and medium in organic content. Annual rain fall is 1000 to1200 mm received generally during mid-June to mid-October.
It is situated in South East of Rohilkhand Division at 27.35 N latitude and 79.37 E longitude geographically. Lakhimpur Khiri, Hardoi, Farrukhabad, Bareilly, Budaun and Pilibhit are the neighboring district of Shahjahanpur. It has 4575 square meter geographical area. Gomti, Ramganga and Garrah are the three main rivers of the district.The tributaries of Gomti are Mensi, Jhukma, Kathana and Suketa, Kai and Khannaut are the tributaries of Garrah.

Figure 1: Geological map of study area

MATERIALS AND METHODS

The techniques which are used to investigate the concentration of Radon, Thoron and their progeny are as follows -

MEASUREMENT OF INDOOR RADON AND THORON CONCENTRATION

Pin –hole based ^{222}Rn /^{220}Rn discriminating dosimeter technique

The measurement of indoor Radon, Thoron concentration in dwellings was done by pin hole based ^{222}Rn /^{220}Rn discriminator dosimeter. The description of calibration and other details of pin hole based ^{222}Rn /^{220}Rn discriminator dosimeter was elsewhere[14].The newly designed dosimeter system has two chambers, which are separated by a central pin hole disc, made up of high density polyethylene materials acting as ^{220}Rn discriminator[15]. This dosimeter contains four pin holes of 1mm diameter and 2mm length in the circular disc as shown in figure 2.
In the present study, we have included 54 residential houses in14 location in the district of Shahajahanpur for the measurement of indoor radon and its progeny.
Following equations are used for the determination of indoor Radon and Thoron concentration

$$\text{Radon concentration } C_R(Bq/m3) = \frac{T_1 - B}{D \times K_R} \quad (1)$$

$$\text{Thoron concentration } C_T\ (Bq/m^3) = \frac{[T_2 - B] - T_1}{D \times K_T} \quad (2)$$

Where T_1 = Track densities observed in radon chamber
T_2 = Track density observed in the "radon + thoron" chamber;
K_R = calibration factor of Radon in "Radon" compartment,
K_T = calibration factor of radon and thoron in the "radon + thoron" chamber
D =number of days of exposure time
B = Background track density arises due to intrinsic properties and exposure during transit period

MEASUREMENT OF RADON AND THORON PROGENY CONCENTRATION

Direct Radon/Thoron progeny sensor techniques (DRPS/DTPS)

Direct Radon and direct Thoron progeny sensors (DRPS AND DTPS) were used to measure concentration of Radon and Thoron Progenies respectively[16]. They consist of passive nuclear track detectors(LR-115) fitted with an absorber of required thickness 50 μ m aluminized Mylar absorber are used for thoron progeny which detect 8.78Mev α- particles whereas for Radon progeny , the absorber is 37 μ m thick and composed of cellulose nitrate and aluminized Mylar which detect mainly 7.67 Mev α- particle. This thickness specially ensures that lower energy α emission(from the gases and other air borne α-emitters) do not pass through the absorber. 54 DTPS and DRPS are suspended with pin hole based Radon /Thoron discriminator in dwelling of study area. Following equations are used to calculate EETC and EERC[17].

$$EETC = \frac{T_1 - B}{D \times S_T} \qquad (3)$$

where "T1 " is the track densities recorded on DTPS, "D" is the number of days exposed, "B" is the background counts, and ST is the sensitivity factor for thoron progeny (0.94 ± 0.027) tracks/cm²/day1 /EETC (Bq/m³).

$$EERC = \frac{T_{Rn} - B}{D \times S_R} \qquad (4)$$

Where S_R= Sensitivity factor for Radonprogeny (0.09 ± 0.0004) tracks/cm²/day/EERC (Bq/m³)

$$T_{Rn} = T_{DRPS} - \frac{\eta_{RT}}{\eta_{TT}} T_{DTPS} \quad (5)$$

Where η_{RT}= is the track registration efficiency for Radon progeny in DRPS.

η_{TT} = is the track registration efficiency for Thoron progeny in DTPS.

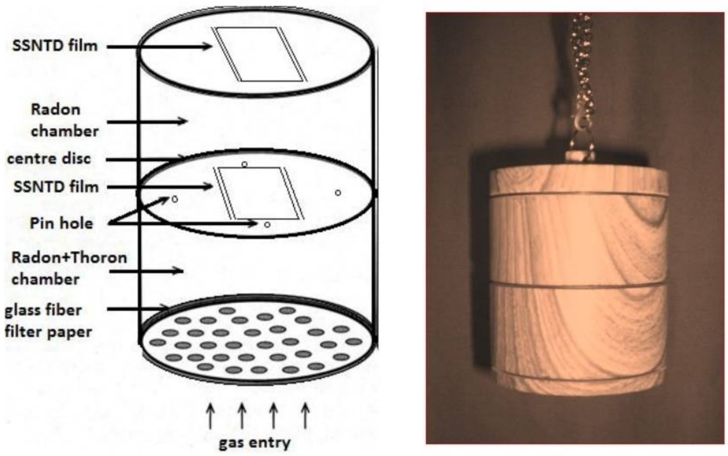

Figure 2: Pin Hole Dosimeter

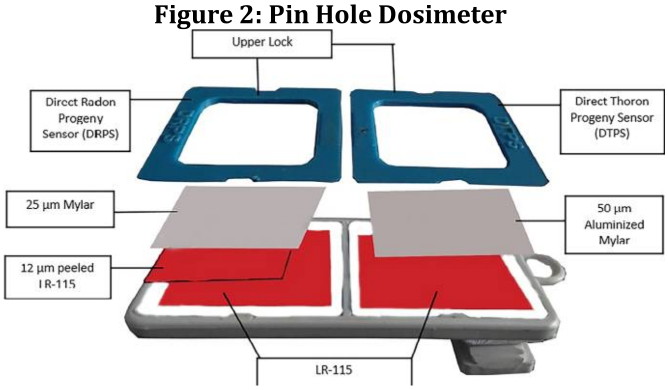

Figure 3: Direct Radon/Thoron progeny sensor (DRPS/DTPS)

RESULT AND DISCUSSION

The LR115 Type II plastic track detector was used to measure the concentration of radon,thoron and their progeny. The seasonal variation and summarized results of indoor radon, thoron and their progeny concentration are shown in Tables below.

Table 1 Seasonal variation of Indoor radon concentration (Bq/m^3) in Shahjahanpur

	Summer			Monsoon			Winter			Autumn		
LOCATION	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
SPN CITY	9	19	15	24	37	31.37	37	57	46.75	32	42	37.25
KAHILIYA	15	19	17.5	24	39	33.75	48	52	50.25	38	45	41.75
ROZA	18	24	21	38	46	43	59	73	66.67	43	56	50
SINDHAULI	12	21	17.67	32	38	35	44	63	54.67	39	47	42.67
KANTH	18	21	19.5	34	46	38	57	72	65.25	49	51	49.5
JALALABAD	14	21	17.2	29	43	37.2	52	69	60	35	43	40
POWAYAN	14	23	16.67	25	37	32.75	54	63	57.75	38	43	40.75
TILHAR	16	21	18	32	38	36.2	48	62	53.6	45	52	49.4
KATRA	10	17	12.67	28	34	31.67	53	64	57.67	34	48	44.67
KANENG	17	24	19.67	36	47	40.67	56	67	60.33	39	48	44.67
MIRAPUR	17	22	19	27	38	33.75	50	64	56	38	47	43.25
JALALPUR	9	19	14	28	35	32	51	55	52.67	32	60	46.33
BHEDPUR	16	16	16	33	36	34.5	62	69	65.5	42	45	43.5
NAHIL	12	20	17	27	35	31.33	38	68	54.33	37	40	39.67

Table2Seasonal variation of Indoor radon progeny concentration (Bq/m^3) in Shahjahanpur

	Summer			Monsoon			Winter			Autumn		
LOCATION	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
SPN CITY	4.76	10.24	7.26	7.12	14.36	12.05	15.25	24.2	19	11.45	16.24	13.1
KAHILIYA	4.47	9.45	6.89	10.98	16.56	13.52	17.46	23.46	19.27	13.67	16.43	14.67
ROZA	6.04	11.45	8.65	11.09	16.72	13.85	16.68	24.89	19.96	13.56	16.08	15.03
SINDHAULI	4.6	9.97	7.66	11.03	12.53	11.88	15.07	21.05	18.06	13.9	17.74	15.54
KANTH	5.04	11.94	7.61	13.62	14.03	13.85	19.32	24.47	21.7	13.46	17.8	15.47
JALALABAD	5.73	11.83	8.58	10.03	20.32	12.50	18.04	23.6	21.22	13.72	18.27	16.49
POWAYAN	7.28	10.24	8.94	11.38	13.9	12.76	23.19	25.42	24.55	14.76	19.37	16.93
TILHAR	5.29	12.39	7.91	12.34	18.22	15.45	16.29	27.21	20.79	13.27	21.29	15.36
KATRA	4.9	11.37	8.55	10.35	13.49	12.07	18.2	21.06	19.56	13.5	17.3	15.36
KANENG	7.2	8.24	7.72	11.52	14.28	12.9	18.2	23.45	21.18	13.36	18.24	15.18
MIRAPUR	5.2	9.32	7.7	11.62	15.28	13.66	16.27	23.88	19.57	13.29	16.93	14.57
JALALPUR	5.28	8.94	7.35	12.27	16.27	14.61	19.02	23.29	20.61	14.92	18.02	16.28
BHEDPUR	6.38	7.93	7.16	12.64	16.38	14.51	16.28	17.04	16.66	17.1	17.43	17.27
NAHIL	6.6	9.83	8.22	13.27	15.45	14.12	16.62	25.82	20.14	15.32	18.24	16.78

Table 3 Summarized results of indoor radon concentration (Bq/m^3) in Shahjahanpur

	SUMMER	MONSOON	AUTUMN	WINTER	AVERAGE
MIN	9.00	24.00	32.00	37.00	28.25
MAX	24.00	47.00	60.00	73.00	48.25
AVE	17.28	34.83	43.15	55.87	37.78
SD	3.46	5.25	5.90	8.34	4.19
GM	16.89	34.44	42.76	55.24	37.55
SE	0.47	0.71	0.80	1.13	0.57

Table 4Summarized results of indoor radon progeny concentration (Bq/m^3) in Shahjahanpur

	SUMMER	MONSOON	AUTUMN	WINTER	AVERAGE
MIN	4.47	7.12	11.45	15.07	11.67
MAX	12.39	20.32	21.29	27.21	18.14
AVE	7.66	7.85	13.5	15.42	20.27
SD	2.05	2.18	2.19	3.17	1.46
GM	7.59	13.33	15.28	20.03	14.26
SE	0.28	0.3	0.3	0.43	0.20

Table 5 Seasonal variation of Indoor Thoron concentration (Bq/m^3) in Shahjahanpur

	Summer			Monsoon			Winter			Autumn		
LOCATION	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
SPN CITY	8	16	10.88	11	19	15.13	17	27	21.75	13	25	17.63
KAHILIYA	9	16	12.75	12	19	16.50	25	34	29.00	19	29	25.25
ROZA	12	17	14.33	14	20	18.00	27	32	30.00	19	28	24.33
SINDHAULI	15	20	16.67	21	29	25.33	25	34	28.67	23	24	23.33
KANTH	10	17	13	14	19	16.75	27	32	29.25	15	26	21.75
JALALABAD	10	18	14.6	17	21	18.60	27	34	29.80	26	29	27.40
POWAYAN	9	14	12	16	21	18.50	27	38	32.50	18	27	22.50
TILHAR	8	17	12.6	18	26	21.60	28	33	30.40	24	28	26.80
KATRA	10	16	12.67	27	30	28.67	31	38	35.00	24	29	26.67
KANENG	15	16	15.67	18	26	21.33	27	33	29.67	25	29	27.00
MIRAPUR	10	16	13.5	18	29	21.50	27	35	30.75	21	33	26.50
JALALPUR	12	17	14.33	16	29	22.00	28	35	32.33	22	25	23.50
BHEDPUR	10	16	13	15	19	17.00	23	25	24.00	22	23	22.50
NAHIL	11	18	13.66	21	26	23.00	28	36	31.00	20	27	24.33

Table 6Seasonal variation of Indoor Thoron progeny concentration (Bq/m³) in Shahjahanpur

	Summer	Monsoon	Winter	Autumn	Average
SPN CITY	0.84	0.89	0.98	0.87	0.90
KAHILIYA	0.89	0.78	0.82	0.79	0.82
ROZA	1.04	0.92	1.11	1.09	1.04
SINDHAULI	0.79	0.83	0.94	0.96	0.88
KANTH	0.72	0.9	1.06	0.73	0.85
JALALABAD	0.96	1.06	1.26	NA	1.09
POWAYAN	0.89	0.88	0.96	0.81	0.89
TILHAR	NA	0.93	0.84	0.87	0.88
KATRA	0.69	0.59	1.05	0.88	0.80
KANENG	0.83	0.75	1.02	0.96	1.14
MIRAPUR	0.69	0.95	0.84	0.76	0.81
JALALPUR	1.07	0.98	0.88	0.85	0.95
BHEDPUR	0.71	0.77	0.95	0.76	0.80
NAHIL	0.73	0.87	0.97	0.82	0.85

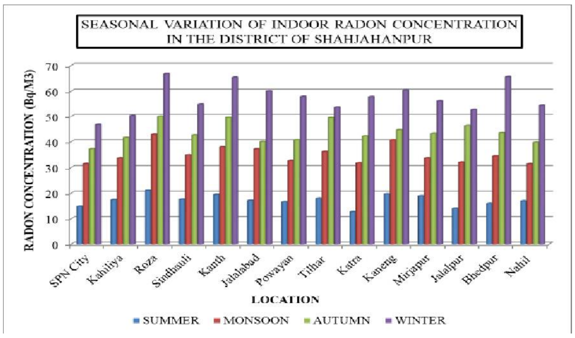

Figure 4: Seasonal Variation of Indoor Radon Concentration

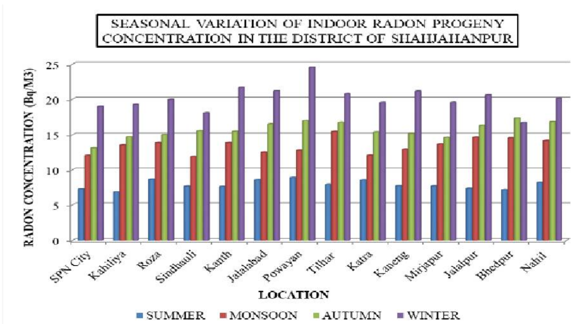

Figure 5: Seasonal Variation of Indoor Radon Progeny Concentration

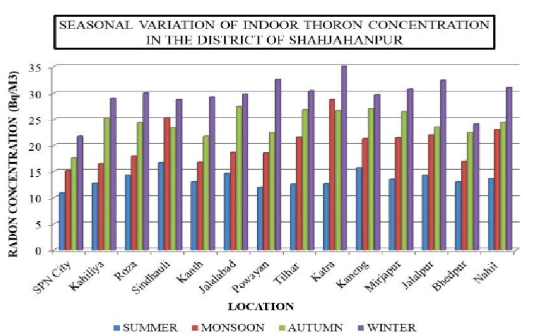

Figure 6: Seasonal Variation of Indoor Thoron Concentration

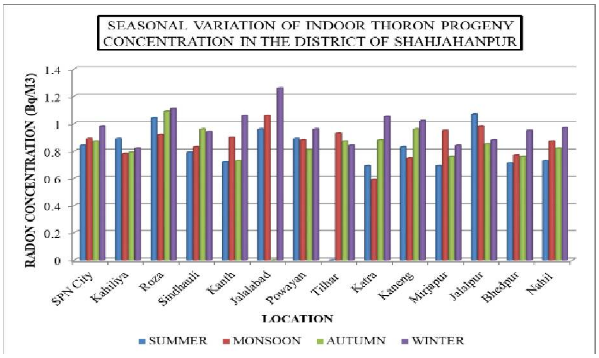

Figure 4: Seasonal Variation of Thoron Progeny Concentration

On the basis of the results it was found that the concentration of indoor radon varied from 9.00Bq/m³to 73.00Bq/m³with an average of 37.78Bq/m³ and geometric mean 37.55Bq/m³ with standard deviation 4.19Bq/m³ and the concentration of radon progeny varied from4.47 Bq/m³ to 27.21 Bq/m³ with an average of 20.27Bq/m³ and geometric mean 14.26Bq/m³ with Standard Deviation1.46Bq/m³.The seasonal variation in concentration of indoor radon their progenies in the residential houses of Shahjahanpur is shown in table 1 and 2 .

In present study it was observed that the concentration of indoor radon during summer season varied from 9 Bq/m³ to 24 Bq/m³ with an average of 17.28 Bq/m³ with Standard deviation 3.46 Bq/m³ and Geometric mean 16.89 Bq/m³ and during monsoon season it varied from 24 Bq/m³to 47 Bq/m³ with an average of 34.83 Bq/m³ with Standard deviation 5.25 Bq/m³ and Geometric mean 34.44 Bq/m³ while in autumn season it varied from 32 Bq/m³to 60 Bq/m³ with an average of 43.15 Bq/m³ with Standard deviation 5.9 Bq/m³ and Geometric mean 42.76 Bq/m³. In winter season it varied from 37 Bq/m³to 73 Bq/m³ with an average of 55.87 Bq/m³ with Standard deviation 8.34 Bq/m³ and Geometric mean 55.24 Bq/m³.

The concentration of radon progeny during summer seasonvaried from 4.47 Bq/m³ to 12.39 Bq/m³ with an average of 7.66 Bq/m³ with Standard deviation 2.05 Bq/m³ and Geometric mean 7.59 Bq/m³, in monsoon season it varied from 7.12 Bq/m³ to 20.32 Bq/m³ with an average of 7.85 Bq/m³ with Standard deviation 2.18 Bq/m³ and Geometric mean 13.33 Bq/m³. In autumn season it varied from 11.45 Bq/m³to 21.29 Bq/m³ with an average of 13.50 Bq/m³ with Standard deviation 2.19 Bq/m³ and Geometric mean 15.28 Bq/m³ and in winter season it varied from 15.07 Bq/m³to 27.21 Bq/m³ with an average of 15.42 Bq/m³ with Standard deviation 3.17 Bq/m³ and Geometric mean 20.03 Bq/m³.

It was found that the concentration of indoor Thoron varied from 8.00 Bq/m³ to 38.00 Bq/m³ with an average of 21.49 Bq/m³ and geometric mean 21.22 Bq/m³ with SD 3.25 Bq/m³. The concentration of Thoron progeny was observed to vary from 0.69 Bq/m³ to 1.05 Bq/m³ with an average of 0.91 Bq/m³ and geometric mean 0.90Bq/m³ with SD 0.11Bq/m³.

During summer season the concentration of indoor thoron varied from 8 Bq/m³ to 20 Bq/m³ with an average of 13.26 Bq/m³ with Standard deviation 2.97 Bq/m³ and Geometric mean 12.92 Bq/m³. In monsoon season it varied from 11 Bq/m³to 30 Bq/m³ with an average of 19.70 Bq/m³ with Standard deviation 4.66 Bq/m³ and Geometric mean 19.18 Bq/m³. During autumn season their value varied from 13 Bq/m³ to 33 Bq/m³ with an average of 23.87 Bq/m³ with Standard deviation 4.36 Bq/m³ and Geometric mean 23.43 Bq/m³ and in winter season varied from 17 Bq/m³to 38 Bq/m³ with an average of 29.06 Bq/m³ with Standard deviation 4.72 Bq/m³ and Geometric mean 28.65 Bq/m³. It is observed that the overall mean value of concentration of indoor thoron is maximum (29.06 Bq/m³) during winter season and minimum (13.26 Bq/m³) during summer season.

During summer season the indoor thoron progeny concentration varied from 0.69 Bq/m³ to 1.07 Bq/m³ with an average of 0.84 Bq/m³ with Standard deviation 0.13 Bq/m³ and Geometric mean 0.83Bq/m³, in monsoon season its concentration varied from 0.59 Bq/m³ to 0.98 Bq/m³ with an average of 0.86 Bq/m³ with Standard deviation 0.12 Bq/m³ and Geometric mean 0.86 Bq/m³. In autumn season its concentration varied from 0.76 Bq/m³ to 0.96 Bq/m³ with an average of 0.86 Bq/m³ with Standard deviation 0.10 Bq/m³ and Geometric mean 0.85 Bq/m³ and during winter season its value varied from 0.89 Bq/m³ to 1.05 Bq/m³ with an average of 0.98 Bq/m³ with Standard deviation 0.12 Bq/m³ and Geometric mean 0.97 Bq/m³.

The average value of concentration of radon in the studied area has been found lower as compared to the average values at national and global level [2, 9, 16, 17]. The average concentrations values of radon, thoron and its progeny have been recorded minimum in the summer season and maximum in the winter season.

CONCLUSION

The concentration of indoor radon, thoron and their progeny was measured by pinhole dosimeter. In the study area, it was found that the concentration of radon, thoron and their progeny have no significant health risk as annual average concentration was found to be lower than the actionable level of 100 Bq/m^3 which is recommended by the world health organization. The result show that indoor radon, thoron and their progeny concentration decreases with increase in number of outlets therefore it is minimum in summer and maximum in winter. The concentration of radon thoron and their progeny have been inferred to be influenced by building design, radon source, ventilation conditions, a living habits of dwellers and geology of the area.

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