The Study Of Radon/Thoron And Progeny Concentration In The District Haridwar, Uttarakhand, India Using SSNTDS

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Abstract
Annual radon and thoron exposure imparts a major contribution to inhalation doses received by the public. we have found the results of Indoor radon and thoron concentrations were measured passively over time in the Haridwar region, with health hazards to residents. In the current study Solid State Nuclear Track Detectors (SSNTDS) based twin chamber dosimeters, i.e. pin-hole dosimeters with LR-115 track detectors, were utilized to estimate Radon (Rn) and Thoron (Rn) gas concentration levels in Haridwar houses. DRPS and DTPS were used for estimating the radon progeny concentration and thoron progeny concentration. The average Radon concentration levels studied in houses were found the values from 15.75 Bq/m^3 to 52.13 Bq/m^3 and thoron concentrations is found to vary from 9.71 Bq/m^3 to 31.89 Bq/m^3 and its corresponding geometric mean of Radon and thoron concentration were found 25.58 Bq/m^3 and 17.04 Bq/m^3.

Keywords: Radon, Thoron, Pin-hole Dosimeter, LR-115 type-II plastic track detector (SSNTDs), DRPS and DTPS

INTRODUCTION

The natural world pollution is a serious problem and because of it life on Earth is in danger since the beginning. Therefore, naturally, we should actively deal with sensitivity to pollutants that threaten human life (Nasir et al., 2012). Such pollutants or radiations are caused by the release of radioactive decay chains of radon and thoron gas. Both of which are found in soil layers and interior finishes, Granite in particular. Radon is a naturally occurring radionuclide that is generated by the decay products of 238U, 235U and 232Th [1-5]. It is a colorless, odorless, radioactive noble gas that quickly reaches the soil's surface. ICE-11, Health Protection Agency, 2009. The half-life of radon 222 and thoron is 3.82 days and 56 seconds, respectively. According to the National Radiation Protection Board (NRPB), natural and synthetic ingestion provide 85% and 15% of effective human doses, respectively. Radon and granite stone strands produce black cement (Folkerts et al., 1984) or have uranium 238 and thorium 232 concentrations (Ramachandran et al., 1989; Turhan et al., 2012) [6-15]. The α radiation gas emitted by radon 222 and its derivatives (218Po and 214Po), as well as its chain length, can damage DNA in the lung's cells and in the end, cause cancer of the lung in people (Taylor-Lang et al., 2012) [16-24]. The World Health Organization has issued a statement of confirmation of the significant link between lung cancer and the prevalence of radon in indoor air. The Environmental Protection Agency (EPA) announced approximately 21,000 deaths due to radon in indoor air, ten times the death rate due to air pollution. EPA and WHO have proposed standard indoor air radon concentrations of 148 Bq/m3 and 100 Bq/m3 (Topçu et al., 2013) [25-30]. Other research indicates that granite stones leak significantly more radon than other building materials. Radioactive substances are present in all construction materials, albeit in small quantities. When it comes to the interior of a home, emissions from building materials and the surrounding soil are the most significant radon concentration factors [31-33].

A measurement technique was used in the current study to measure indoor concentrations of radon and thoron in the district Haridwar using a pin-hole dosimeter developed by BARC Mumbai and a solid-state fingerprint detector (LR-115) reservoir-based direct radon progeny sensors and direct thoron progeny sensors (DRPS/DTPS). Houses were selected based on different types of buildings and geographic locations. The GPS coordinates of each house were also recorded. Dosimeters and DRPS/DTPS were installed during the year to conduct a proper site assessment [34-38].

STUDY AREAS

The study area selected for this work is Haridwar Sites, Uttarakhand State, India. Figure (1) shows the geographic location of the study area of Haridwar district.

Fig.1

Uttarakhand is a state in North India. Haridwar is a district in Uttarakhand, India. In the west, Saharanpur, in the north, Dehradun, in the east, Pauri Garhwal, and in the south, Muzaffarnagar and Bijnor. The total size of Haridwar district is 2360 km2. The latitudinal and longitudinal extent of the district is 29.580 North and 78.130 East, and it is situated at an altitude of 249.7 meters above sea level. (MSME Report 2007 by Government of India). Haridwar, the gateway to the gods, is a famous pilgrimage site located on the banks of the Ganges and is referred to as Mayapuri in the Puranas. Haridwar has existed since 2000 BC. Saffron-colored pottery from the last period of the Indus Valley Civilization has been found in the district (Haridwar Statistical Diary, 2016). Haridwar has emerged as a major economic hub thanks to its good transportation network with neighboring states. Trains connect the major tourist attractions of Haridwar to almost every part of India. The nearest airport is Jolly Grant in Dehradun (58.2 km). Every year, more than 8 million pilgrims visit Haridwar (Nikhil Monga et al. 2016).

Archaeological discoveries show that the Terracotta culture existed around 1700 BC. Saharanpur is to the west, Dehradun to the north and east, Pauri Garhwal to the east, and Muzaffarnagar and Bijnor to the south. The district headquarters is around 12 kilometers from the Roshnabad railway station. Haridwar is one of the first cities where the Ganga comes into the plains from the Himalayas. Since Haridwar is situated on the banks of the Ganges, water resources are abundant here, and practically all types of food grains are grown in abundance. As a study area, we divided the Haridwar district into seven sections: Haridwar, Jwalapur, Roorkee, Bahadurabad, Bhagwanpur, Sidhru and Kherki, where we studied radon thorons and their progeny found concentration.

METHODOLOGY

A methodology was explained by the following techniques.

Measurement Techniques 1. Radon levels are measured using a radon/thoron differential pin-hole dosimeter. Pin-hole technology is a device that has a quick response time of 222Rn. Making a 220Rn discriminator is really useful for online radon measurement. The schematic diagrams of the pin-hole dosimeter are shown in Fig.2

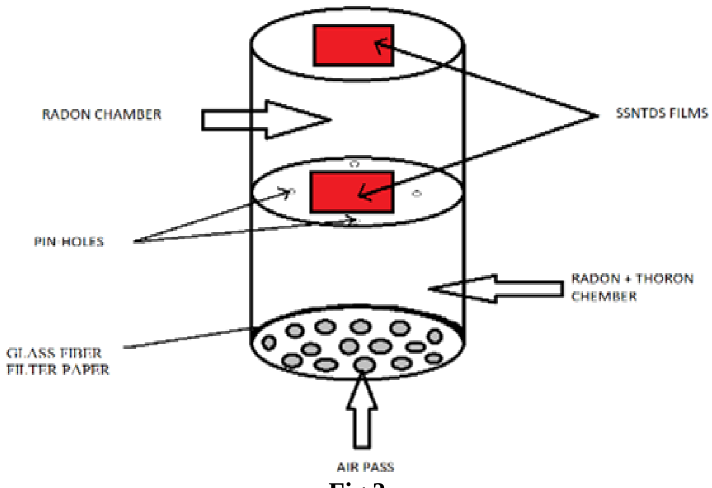

Fig 2.

By selecting the appropriate chamber volume and hole diameter, it is possible to limit 220Rn access to the chamber volume. This dosimeter system's novel design features two chambers separated by a central aperture disc that works as a 220Rn discriminator. The dosimeter has a single entrance in which gas passes through fiberglass filter paper (0.56 m) into the first compartment, i.e. H. "Radon + thoron" chamber, and then into the second chamber, through the hole in the "radon" chamber, preventing 220Rn from entering this chamber. Each chamber is 4.1 cm long and 3.1 cm in radius. Internally covered with metal powder, the chambers give zero electric fields within the chamber volume, allowing the field to be measured within the chamber volume. The accumulation of gas progeny will be uniform over the volume. This design eliminates the need for membrane filters in favor of pin-hole separators. This removes the possibility of negative 220Rn concentrations encountered earlier. In some cases, the same gas may enter both chambers.

The dosimeters are installed in houses for three months. The LR115 films retrieved from the dosimeters were immersed in a NaOH solution of normality 2.5 N at 60 °C for 90 minutes. After etching, the detector must be removed from its cellulose acetate base and the tracks matched using a spark counter. Before these measurements, the functioning should be identical, and the pre-sparking voltage of the spark counter should be calculated. The relative factor of the spark counter must also be calculated by comparison. There is a reference spark counter in the BARC laboratory.

The estimated concentrations of 222Rn (CR) and 220Rn (CT) are obtained by the following equations 1 and 2 [39-42].

$$\mathbf{C_{\dot{R}}} = \frac{\mathbf{T_1 - B}}{\mathbf{d\ K_R}} \quad \mathbf{(1)}$$

$$\mathbf{C_T} = \frac{\mathbf{T_2 - d\ C_R\ K'_R - B}}{\mathbf{d\ K_T}} \quad \mathbf{(2)}$$

Where,
T_1=Radon chamber track density
T_2 = 'Radon + thoron' chamber track density
K_R = Calibration factor in the 'radon' chamber (0.017 tr.cm-2.d-1/Bq/m^3)
d = Exposure days
K'_R= Calibration factor in 'radon+thoron' chamber (0.0172 tr.cm-2.d-1/Bq/m^3)
K_T = Calibration factor of thoron in 'radon+thoron' chamber (0.010 tr.cm-2.d-1/Bq/m^3)
B = background tracks

Measurement Techniques 2.
The concentration of Radon progeny Po-214 and Thoron progeny Po-212 was determined using DRPS/DTPS. The schematic diagrams of DRPS and DTPS are shown in Fig. 3.

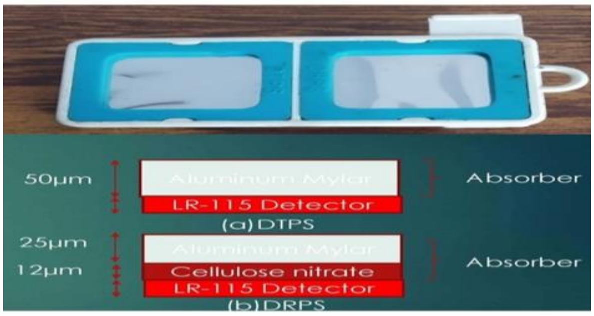

Fig. 3

In LR115 solid-state nuclear detectors, direct progeny sensors selectively record traces generated by progeny deposition activity. To detect different particle energies, the absorber thickness is adjusted. The effective absorber thickness of radon and thoron progeny is 37 micrometers (25 aluminized mylar+12 cellulose nitrate) and 50 micrometers (aluminized mylar), respectively. These record tracks are caused by particles released by Po-214 (energy 7.69 MeV) plus Po-212 (energy 8.78 MeV) and Po212 (energy 8.78 MeV), respectively.

Because the film in DRPS is exposed to both radon and thoron progeny, the radon and thoron progeny tracks are deleted to calculate EERC and EETC, respectively. Because the system is designed to work in deposition mode, it is critical to avoid uncontrolled static deposition. To prevent uncontrolled static deposition, the aluminized face of the LLR film was used as the deposition surface (Mishra, 2014).

The following formulas are used to determine EERC and EETC (equilibrium equivalent concentration for radon and thoron progeny) which are obtained from equations 3 and 4 [42-44].

$$\boldsymbol{EERC\ (Bq/m^3)} = \frac{\mathbf{T_3}}{\mathbf{k_R\ d}} \quad \mathbf{(3)}$$

$$EETC\ (Bq/m^3) = \frac{T_4}{k_T\ d} \quad (4)$$

Where,
T_3= track density in DRPS as a result of radon progeny.
T_4=DTPS track density owing to thoron progeny.
K_R = Radon progeny calibration factor, 0.09 tracks cm-2d-1 per EERC (Bq/m^3).
K_T = thoron progeny calibration factor, 0.94 tracks cm-2d-1 per EETC (Bq/m^3).

RESULT AND DISCUSSION

Tables 1 and 2 demonstrate the seasonal variations of indoor 222Rn, 220Rn, EERC, and EETC for four cycles in the year. Indoor radon concentrations range from 15.75 Bq/m^3 to 52.13 Bq/m^3, and geometric mean value of 25.78 Bq/m^3 with standard deviation of 12.31 in the whole seasonal year and Indoor thoron concentrations range from 9.71 Bq/m^3 to 31.89 Bq/m^3 and a geometric mean value of 17.04 Bq/m^3 with standard deviation 7.81 Bq/m^3. The annual variation of 222Rn and 220Rn concentrations is found to be in a range.

According to the literature review, the regional geology of the monitoring stations and climate variables such as indoor and outdoor temperature fluctuations, humidity, air conditions, and radon levels were all important. If no escape route is developed, these gases can accumulate inside homes. In the district, Haridwar dosimeters were installed in 35 houses in Bhagwanpur, Roorkee, Bahadrabad, Jawalapur, Haridwar, Devpur and Sidharu throughout the season. During the third cycle, the concentration of radon was found to be 75.38 Bq/m^3 in the village Sidharu which is higher than in other villages, Roorkee, Bahadrabad, Jawalapur, Haridwar, Devpur and the maximum thoron concentration was found to be 52.37 Bq/m^3 in the village Bhagwanpur which is higher than Roorkee, Bahadrabad, Jawalapur, Haridwar, Devpur and Sidharuas shown in Table 1.

Table 1: Radon And Thoron Concentration

S.N.	Location	Average of C_R session Bq/m^3				Total Avg. of C_R	Average of C_T session Bq/m^3				Total Avg. of C_T
		I	II	III	IV	Bq/m^3	I	II	III	IV	Bq/m^3
1	Bhagwanpur	10.15	34.55	12.81	59.13	29.16	4.52	22.44	7.19	52.37	21.63
2	Roorkee	38.04	22.48	6.75	21.66	22.23	25.93	16.00	4.07	16.89	15.72
3	Bahadrabad	31.33	33.25	31.50	19.39	28.87	25.59	29.41	25.78	11.26	23.01
4	Jawalapur	25.45	34.99	38.13	17.12	28.92	8.30	21.33	26.15	11.48	48.00
5	Haridwar	9.11	11.15	24.75	18.00	15.75	6.15	6.59	17.93	10.22	10.22
6	Devpur	11.37	13.07	29.06	10.94	16.11	7.26	10.37	15.19	6.00	9.85
7	Sidharu	34.68	41.26	75.38	57.21	52.13	26.22	28.67	37.48	35.19	31.89
	AVG	22.88	27.25	31.20	29.06	27.60	14.85	19.26	19.11	20.49	22.90
	MAX	38.04	41.26	75.38	59.13	52.13	26.22	29.41	37.48	52.37	48.00
	MIN	9.11	11.15	6.75	10.94	15.75	4.52	6.59	4.07	6.00	9.85
	GM	19.59	24.59	24.71	24.15	25.58	11.65	17.18	15.36	15.81	19.83
	SD	12.46	11.75	22.29	20.16	12.31	10.41	8.72	11.67	16.97	13.51

Table 2: DRPS And DTPS Concentration

S.N.	Location	Average of DRPS session Bq/m^3				Total Avg. of DRPS	Average of DTP Session Bq/m^3				Total Avg. of DTPS
		I	II	III	IV	Bq/m^3	I	II	III	IV	Bq/m^3
1	Bhagwanpur	0.70	6.19	1.48	5.08	3.36	0.29	0.30	0.08	0.54	0.30
2	Roorkee	6.05	0.49	0.88	0.82	2.06	1.00	0.27	0.25	0.17	0.42
3	Bahadrabad	5.88	1.67	2.65	3.48	3.42	0.69	0.73	0.63	0.63	0.67
4	Jawalapur	1.03	4.75	4.07	2.39	3.06	0.05	0.60	0.43	0.25	0.33
5	Haridwar	0.82	2.00	2.49	7.49	3.20	0.07	0.04	0.59	0.61	0.33
6	Devpur	1.21	0.91	5.76	0.80	2.17	0.26	0.35	0.55	0.14	0.33
7	Sidharu	0.53	4.57	2.84	12.35	5.07	0.17	1.26	1.13	0.88	0.86
	AVG	2.32	2.94	2.88	4.63	3.19	0.36	0.51	0.52	0.46	0.46
	MAXI	6.05	6.19	5.76	12.35	5.07	1.00	1.26	1.13	0.88	0.86
	MINI	0.53	0.49	0.88	0.80	2.06	0.05	0.04	0.08	0.14	0.30
	GM	1.45	2.13	2.48	3.07	3.07	0.23	0.35	0.41	0.38	0.43
	SD	2.50	2.20	1.63	4.15	1.00	0.35	0.40	0.33	0.28	0.22

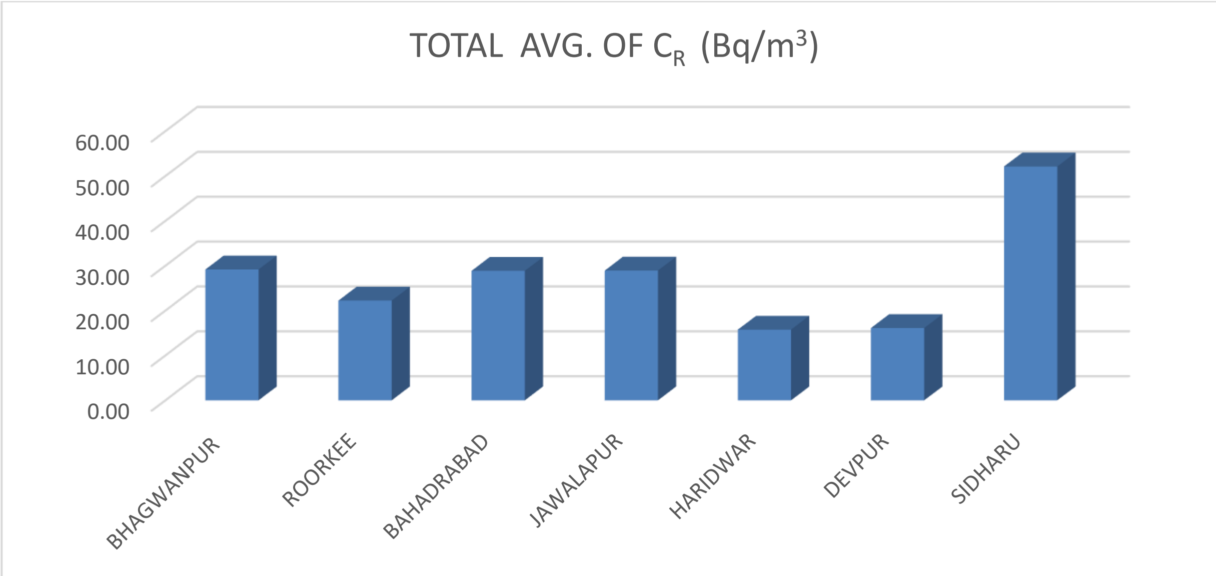

Fig. 4. Total average of Radon concentration

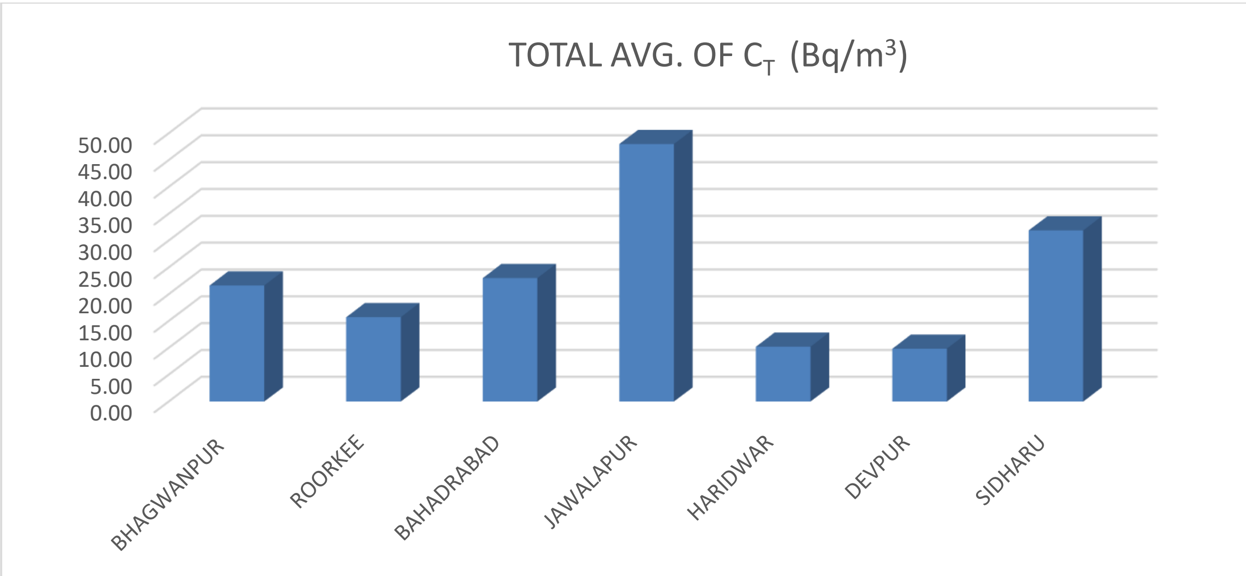

Fig. 5. Total average of Thoron concentration

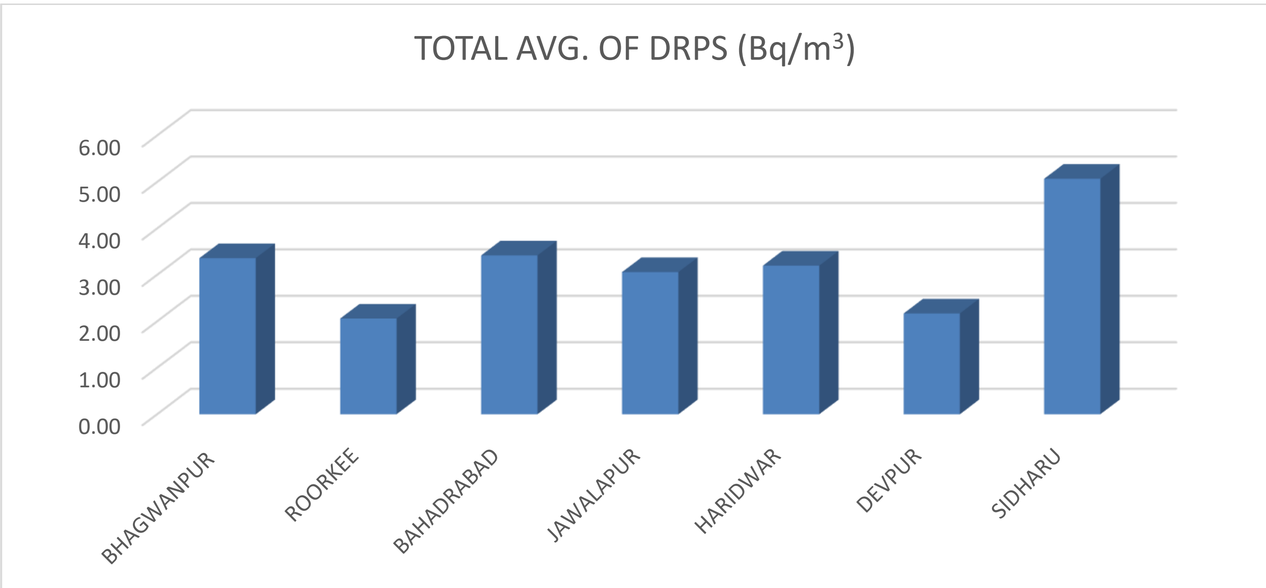

Fig. 6. Total average of DRPS concentration

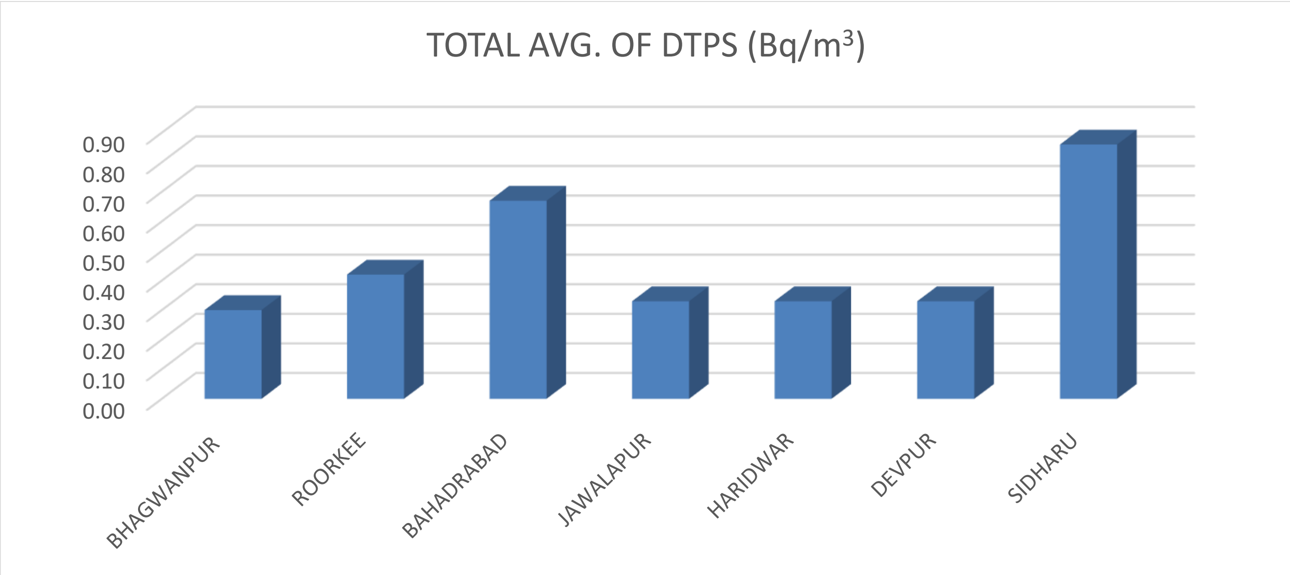

Fig. 7. Total average of DTPS concentration

Table No. 1 summarizes the resultant seasonal variation of indoor radon and thoron concentrations.
The first cycle explained that the maximum radon concentration was found to be 38.04 Bq/m^3 in Roorkee and the lowest radon concentration was found to be 9.11 Bq/m^3 in Haridwar while the maximum thoron concentration was found to be 26.22 Bq/m^3 in Sidharu and the lowest thoron concentration was found to be 4.52 Bq/m^3 in Bhagwanpur.
In the second cycle the maximum radon concentration was found to be 41.26 Bq/m^3 in Sidharu and the lowest radon concentration was found to be11.15 Bq/m^3 in Haridwar while the maximum thron concentration was found to be 29.41 Bq/m^3 in Bahadrabad and the lowest thoron concentration was found to be 6.59 Bq/m^3 in Haridwar.

In the third cycle the maximum radon concentration was found to be 75.38 Bq/m^3 in Sidharu and the lowest radon concentration was found to be 6.75 Bq/m^3 in Roorkee while the maximum thron concentration was found to be 37.48 Bq/m^3 in Sidharu and the lowest thoron concentration was found to be 4.07 Bq/m^3 in Roorkee.
In the fourth cycle the maximum radon concentration was found to be 59.13 Bq/m^3 in Bhagwanpur and the lowest radon concentration was found to be 10.94 Bq/m^3 in Devpur while the maximum thron concentration was found to be 52.37 Bq/m^3 in Bhagwanpur and the lowest thoron concentration was found to be 6.00 Bq/m^3 in Devpur.
The distribution of 222Rn and 220Rn is influenced by a variety of circumstances, including emissions. 222Rn and 220Rn radionuclides originate from fractures or gaps in building floors or walls due to the pressure gradient between interior and outdoor surroundings. The reported increase in levels in certain residences could be attributed to residents' lifestyle choices, such as whether or not they keep their windows and doors open, resulting in limited airflow. The reported increase in levels in certain residences could be attributed to residents' lifestyle choices, such as whether or not they keep their windows and doors open, resulting in limited airflow.

Table 2 summarizes the resultant values of indoor progeny concentrations EERC and EETC.
In the first cycle, EERC ranges from 0.53 Bq/m^3 to 6.05 Bq/m^3 with an average of 2.32Bq/m^3, and a geometric mean of 1.45 Bq/m^3 with a standard deviation of 2.50 Bq/m^3 while EETC ranges 0.05 Bq/m^3 to 1.00 Bq/m^3 with an average of 0.36 Bq/m^3 and geometric mean of 0.23Bq/m^{3}with standard deviation of 0.35 Bq/m^3.
In the second cycle, EERC ranges from 0.49 Bq/m^3 to 6.19 Bq/m^3 and an average of 2.94Bq/m^3, a geometric mean of 2.13 Bq/m^3 and a standard deviation of 2.20 Bq/m^3 while EETC ranges from 0.04 Bq/m^3 to 1.26 Bq/m^3 and average of 0.51 Bq/m^3, a geometric mean of 0.35 Bq/m^3 and standard deviation of 0.40 Bq/m^3.
In the third cycle, EERC ranges from 0.88 Bq/m^3 to 5.76 Bq/m^3 and an average of 2.88 Bq/m^3, a geometric mean of 2.48 Bq/m^3 with a standard deviation of 1.63 Bq/m^3 while EETC ranges from 0.08 Bq/m^3 to 1.13 Bq/m^3 and an average of 0.52 Bq/m^3, with a geometric mean 0.41Bq/m^3 and standard deviation of 0.33 Bq/m^3.
In the fourth cycle, EERC ranges from 0.80 Bq/m^3 to 12.35 Bq/m^3 and an average of 4.63Bq/m^3, a geometric mean 2.48 Bq/m^3 and a standard deviation of 1.63 Bq/m^3 while EETC ranges from 0.14 Bq/m^3 to 0.88 Bq/m^3 and an average of 0.46 Bq/m^3, a geometric mean of 0.38 Bq/m^{3}and standard deviation of 0.28 Bq/m^3.

Conclusions

In current investigations, radon concentrations were shown to be higher than thoron concentrations. Environmental influences on gases and the solid decay products they generate include temperature and pressure gradients, moisture content, and ventilation conditions. The overall concentration of thoron progeny was found to be lower than overall concentration of radon progeny due to radon progeny deposition being faster on detector surfaces than thoron progeny deposition. According to the current findings, decay product concentrations are within the permissible limits.

During the third cycle, environmental concentrations and their progeny levels was found maximum value at some palace as compared to other. Because of the lower temperatures recorded in Haridwar throughout the winter, most windows and doors in dwellings have been kept shut, preventing air exchange from outside to inside. As a result, radioactive gasses have accumulated inside homes, as well as a high rate of 222Rn and 220Rn emissions from the topsoil. Cracks in walls and flooring may form during the winter months. Levels were found to be lower during the summer season, owing to ventilation conditions in houses due to cooling devices during this season, which allowed radioactive gasses to easily escape outside. The levels were lower during the rainy season because of the atmospheric moisture content, which may have hindered radioactive gas exhalation.

Exposure to indoor radioactive emissions has resulted in the use of superior building materials for walls and floors in modern homes, such as granite, plaster stone, and tiles. Furthermore, it is consistent with the prior study's findings. Radon concentrations have been observed to be higher in earthen dwellings than in contemporary dwellings, possibly due to continued diffusion as a result of considerable pollution, mineral emissions from walls, as well as gaps in connections between open floors, walls, and ceilings. Cement buildings got the lowest 220Rn and 222Rn values. The distribution of radionuclides is impacted. However, comparing these results to those of other studies reveals that the outcomes are, on average, comparable (which cannot be assumed). There is variation in radionuclide distribution throughout the study region and even within the same type of housing. It is also influenced by the air exchange rate and ventilation. As a result, one may claim that radiation levels are influenced by geology as well as other factors.

Radon thoron levels detected were lower than the WHO 2009 recommended range of 100-300 Bq/m^3. Seasonal data comparisons revealed that indoor radionuclides EERC, EETC, 222Rn, and 220Rn were lower in the summer than in the wet and winter seasons. Due to limited ventilation throughout the winter, these radionuclides concentrate more within residences, resulting in increased exposure. According to data analysis by housing type, levels were greater in contemporary and mud-type homes than in traditional and other categories. As a result, radon concentrations are higher than thoron concentrations, and EERC concentrations are higher than EETC concentrations throughout the season.

ACKNOWLEDGEMENT

The authors sincerely thank the H.N.B. University (SRT Campas), Badshahi thol Tehri Garhwal and the research group of the Department of Physics, Maharaj Singh College Saharanpur for their constant help during the work. Furthermore, the authors express their appreciation to the participants who provided access to their houses for data gathering.

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