Estimation Of Radon, Thoron, And Their Progeny Concentration In Selected Dwellings Near The Sugar Mills Of Uttar Pradesh And Uttarakhand, India

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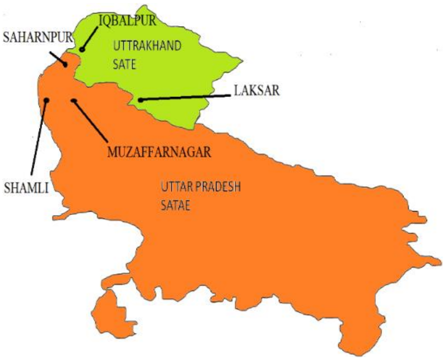
Abstract
Radon gas is the prime contributor to natural radiation and poses a significant human health risk. Radon is the second leading cause of cancer after smoking. The estimation of the level of naturally occurring gases become important for determining radiation risk and has been the subject of interest of researchers worldwide. In the present study, the survey of radon, thoron, and their daughter's product concentration has been carried out in the dwelling situated nearby selected sugar mills of Uttar Pradesh and Uttarakhand state of India by using a pin-hole dosimeter and direct radon/thoron progeny sensor with LR-115 Solid State Nuclear Track Detector (SSNTDs). The results show that the average value of radon and thoron concentration varied from 28.37 Bqm^{-3} to 43.02 $Bqm^{-}3$, and 17.67 Bqm^{-3} to 25.04 Bqm^{-3} respectively. The average value of radon and thoron progeny concentration varied from 6.71 Bqm^{-3} to 14.16 $Bqm^{-}3$, and 0.70 Bqm^{-3} to 1.41 Bqm^{-3} respectively.

Keywords: Fly ash, Pin-hole Dosimeter, (SSNTDs) LR-115 type-II films, Radon, Thoron, DRPS, and DTPS.

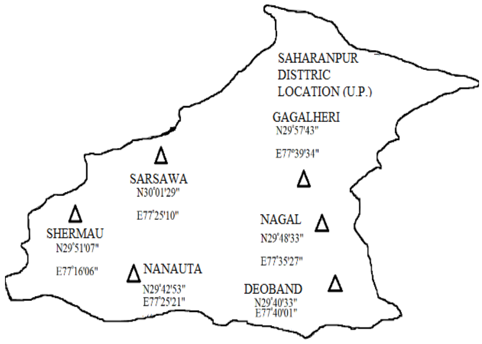
Introduction
Radon is a radioactive element of the uranium decay series which is present in the environment everywhere on the earth. It is found inside the ground, hills, and coal mines in gas form. Firstly, this was discovered in the 16^{th} century in Schneeberg, Germany because in those days mineworkers in Germany had been suffering from lung cancer diseases for a long time. The research found that workers most of spend their time in coal mines, where radioactive elements of uranium series radon ^{222}Rn are present and enter their body by the inhalation of workers for a long time, by which lung and their parts affect. Due to this effect, a new disease occurs known as lung cancer. Therefore, all the world's scientists are researching radon concentration in different countries, so the reference level of radioactive environment for human living can be detected and radon cannot affect health in those places. Hultquist measured the value of radon in the dwellings of Sweden residents in 1956 and found that the indoor, radon concentration values are higher than in outdoor dwelling houses. So far, radon radiation has been present in the earth's atmosphere in both natural and manmade ways. Thoron presents in the atmosphere a short half-lifetime and radon lasts longer according to half-life time. The effect of radon on the human body is greater than thoron because it has a half-life time of radon 3.8 days in the environment. According to the WHO report, humans spend the maximum time in the house and the least time spent out of the house. Therefore, radon affected humans indoors for a long time because all houses made of concrete and cement contain some number of radioactive elements [1-11]. All industries factories, thermal power plants, and mills have played the main role in atmosphere pollution for a long time. Sugar mills and thermal power plants are using poor-quality coal for their production. Coal is a combination of radioactive elements containing uranium, thorium, and potassium. Ash is two types bottom ash and fly ash which are generated by thermal power plants and sugar mills. Fly ash naturally arises in the form of black smoke after burning coal from thermal power plants and chimneys of sugar mills [12-24]. This type of ash is spread around the nearby land and house with aerosol phase containing radionuclide of considered as naturally occurring radioactive materials. Bottom ash and fly ash are primarily made of SiO_2 , $Al_2\ O_3$,FeO_3 , CaO, and a minor number of titania, magnesia, etc. but have a higher content of unburned carbon. The evaluation of both ashes remains a global environmental problem. Ash is used as a base material in both the industrial and resident construction fields where people spend their whole lives. Annual production of fly ash averages 112 million to 250 million tons annually. [25]. The waste of chemicals water combination occurs in liquid form and spreads in the agricultural field and this type of water is absorbed by the crop plants, and trees, and solid form black ash also spreads around them. It also affects the concentration of radon thoron and their progeny [26-30]. Due to this the concentration of radon thoron and their progeny is different in different locations. Radon radiation is the second cause of human lung cancer because human

radon gas is inhaled by alpha decay in the lungs [31-40]. The purpose of this study is to know how much impact sugar mills have on human living by fly ash and chemical water, to this, four-quarter samples have been collected seasonally in all selected areas in a year.

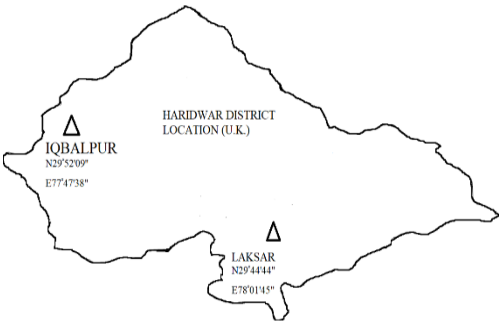
Study area



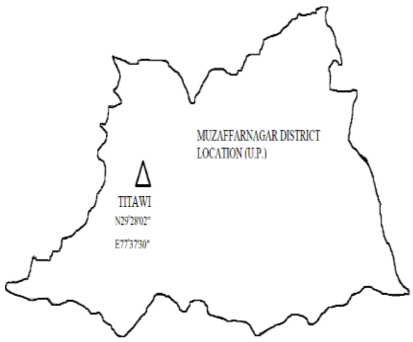
(a) U.P. and U.K.



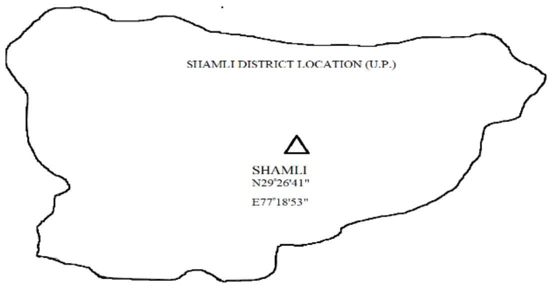
(b) SAHARANPUR



(c) IQBALPUR, LAKSAR



(d) MUZAFFARNAGAR



(e) SHAMLI

Fig.1. (a) Uttar Pradesh and Uttarakhand states. (b) Haridwar district. (c) Saharanpur district. (d) Muzaffarnagar district. (e) Shamli district.

The selected areas of study of radon, thoron, and their progeny concentration are dependent on the sugarcane Factory area in Uttar Pradesh (U.P.) and Uttarakhand (U.K.) of India shown in Fig.1(a). Each location is in India's Northern Region, although they differ from one another in terms of population, amount of rain, environment, agricultural land, rivers, and the number of industrial areas. India is the country that produces the most sugar worldwide. More than 12 states in India produce sugar from sugar cane with 46 mills, Uttara Pradesh leads the country in sugar production at 46.75 % of all sugar produced in India and Uttarakhand is in 10th place with 10 mills 1.67 % production of total sugar in India at. The locations of all these mills are different in the Uttar Pradesh and Uttarakhand states. Fig.1(b), (c), (d), and (e) show the locations of all selected sugar mills with co-ordination Iqbalpur, Laksar, N 29˚ 52ˈ 09" E 77˚ 47ˈ38", N 29˚ 44ˈ 44" E 78˚ 01ˈ45"respectively in the U.K. and Deoband, Nagal, Gagalheri, Nanauta, Sarsawa, Shermau, Shamli, and Titawi N 29˚ 40ˈ 33" E 77˚ 40ˈ01", N 29˚ 48ˈ 33" E 77˚ 35ˈ27", N 29˚ 57ˈ 43" E 77˚ 39ˈ34", N 29˚ 42ˈ 53" E 77˚ 25ˈ21", N 30˚ 01ˈ 29" E 77˚ 25ˈ10", N 29˚ 51ˈ 07" E 77˚ 16ˈ06", N 29˚ 26ˈ 41" E 77˚ 18ˈ53", N 29˚ 28ˈ 02" E 77˚ 77ˈ30"respectively in the U.P. Pine-hole dosimeter have been placed both states locations where there are houses near and around sugar mills for each every three months cycles in a year and collected samples after complete 90 days from deployed LR-115 films.

A complete year is divided into four quarters namely the First quarter (Feb. to April), the second quarter (May to July), the third quarter (Aug. to Oct.), and the fourth quarter (Nov. to Jan.).

Experimental Methods, Materials, and Formulas

(A) Evaluation of radon thoron concentration

The pin-hole dosimeter (apparatus)was used to find out the concentration of radon thoron. This device was made by the BARC science laboratory in Mumbai. One side air entry Pin hole dosimeter is divided into two equal parts (Radon + thoron chamber and Radon chambers). Each chamber is a cylindrical shape and coated aluminum with plastic. Both chamber lengths are 4.1 cm and radius 3.1 cm and two discs are placed on top of each chamber in which fixed (SSNTDs) LR-115 type-II (red-dyed cellulose nitrate emulsion) films with thickens 12µm. Each disc contains four holes 2mm in length and 1mm in radius through which air passes from one chamber to another chamber. A water main paper was placed on the holes of the air entry area. The half-life of radon gas is greater than thoron, so radon is present in the environment long time as like in a pin-hole radon chamber. The pin-hole dosimeters were placed in every location for one year in four equal quarters, each quarter's time period was 90 days for changing the film.

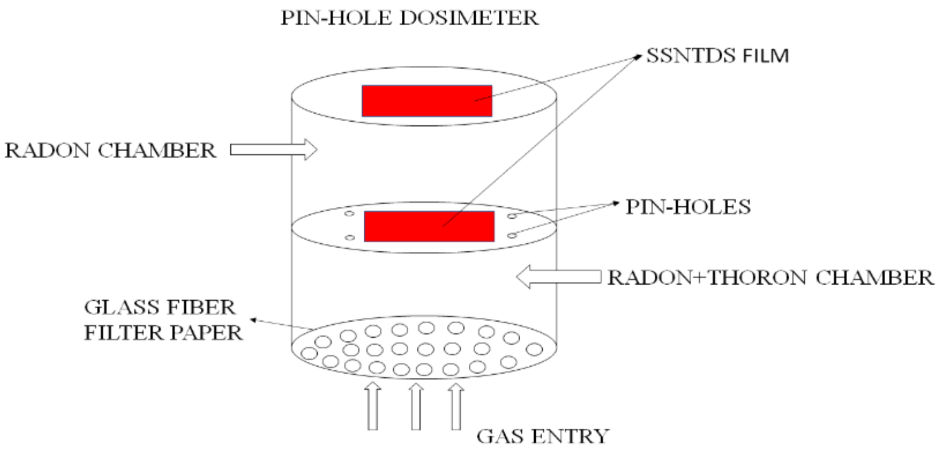


Fig.2: - Internally diagram of pin-hole dosimeter

Removed after completing the deployed time off (SSNTDs) LR-115 type-II films from all the dosimeters. then chemical etching in 2.5 NaOH solution of 1000 ml distills water for 90 minutes at 60˚ temperature. In this etching process, undeveloped tracks are clearly visualized and counted by the spark counter. The average concentration of radon thoron and their progeny were calculated by the following formulas:

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

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

Where,

C_R = Radon concentration (Bqm^{-3}).

C_T = Thoron concentration (Bqm^{-3}).

T_1 = Track density of radon.

T_2 = Track density of thoron.

B = Background data of film.

d = Number of days of exposure.

K_R = Calibration factor of radon (0.017 tr cm^{-2} d^{-1} per Bqm^{-3}).

K'_R = Calibration factor of radon (0.017 tr cm^{-2} d^{-1} per Bqm^{-3}).

K_T = Calibration factor of thoron (0.010 tr cm^{-2} d^{-1} per Bqm^{-3}).

(B) Evaluation of radon and thoron progeny concentration

Radon thoron progeny are calculated with the help of DPS (Direct progeny sensor), which is divided into two parts DRPS (Direct radon progeny sensor) and DTPS (Direct thoron progeny sensor). DPS is deployed at each location selected in the study areas. In the DRPS part, a complete, LR-115 film(112µm) + only nitrocellulose film without plastic(12µm) + aluminize mylar film(25µm) is placed and similarly, in the DTPS part (SSNTDs) LR-115 type-II films (112µm) + 2 aluminize mylar film(25µm) placed.

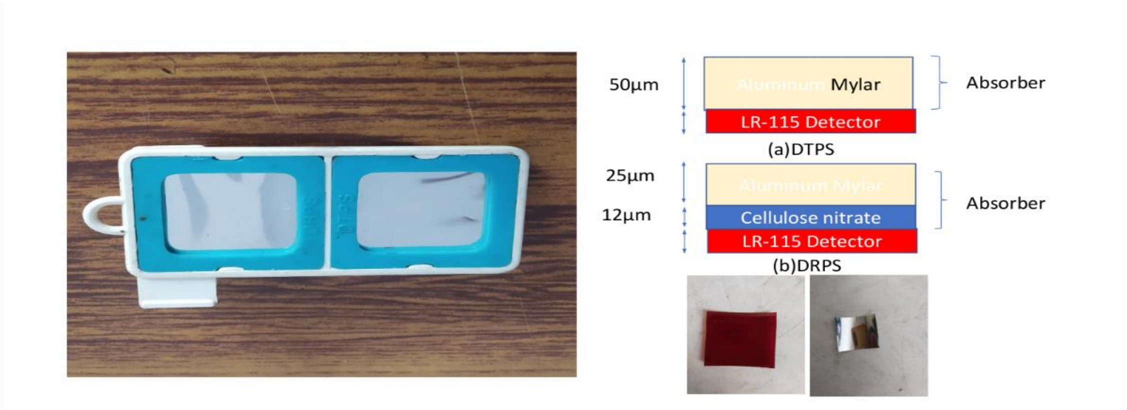


Fig.3: DRPS and DTPS schematic diagram

DRPS is exposed to both radon thoron progeny. So, we calculated the EERC track generated by the thoron progeny is removed as calculated from DTPS. This system is designed to operate in deposition mode to prevent uncontrolled statics from affected deposition rates, therefore aluminum face of mylar film was chosen as the deposition surface.
The calculated formula of EERC (Equilibrium equivalent concentration for radon progeny) and EETC (Equilibrium equivalent concentration for thoron progeny) are given as follows:

$$\boldsymbol{EERC}\ (\mathbf{Bq}\ \boldsymbol{m}^{-3}) = \frac{\mathbf{T_3}}{\mathbf{k_R\ d}} \qquad \textbf{(3)}$$

$$\boldsymbol{EETC}\ (\mathbf{Bq}\ \boldsymbol{m}^{-3}) = \frac{\mathbf{T_4}}{\mathbf{k_T\ d}} \qquad \textbf{(4)}$$

Where,
T_3 = Track density of radon recorded in DRPS.
T_4 = Track density of thoron recorded in DTPS.
k_R = Calibration factor of radon progeny (0.09 track $cm^{-2}d^{-1}$ per EERC (Bqm^{-3}).
k_T = Calibration factor of thoron progeny (0.94 track cm^{-2} d^{-1} per EETC (Bqm^{-3}).

Result and discussion

Table 1: Radon concentration of all quarter

S.N.	Location names	(C_R) First Quarters Bqm^{-3}	(C_R) Second Quarters Bqm^{-3}	(C_R) Third Quarters Bqm^{-3}	(C_R) Fourth Quarters Bqm^{-3}
1	IQBALPUR	83.49	30.20	34.95	42.92
2	LAKSAR	36.49	28.54	21.92	27.97
3	DEOBAND	35.64	30.98	28.32	20.13
4	NAGAL	49.32	31.50	19.96	51.02
5	GAGALHERI	18.65	30.46	22.92	90.98
6	NANAUTA	23.97	19.87	29.19	40.87
7	SARSAWA	56.17	21.13	46.93	45.40
8	SHERMAU	62.40	34.12	25.88	25.75
9	SHAMLI	35.03	36.12	20.39	39.08
10	TITAWI	29.02	20.83	35.47	72.59
	AVERAGE	43.02	28.37	28.59	45.67
	MAX	83.49	36.12	46.93	90.98
	MIN	18.65	19.87	19.96	20.13
	G.M.	39.18	27.80	27.58	41.52
	S.D.	19.83	5.76	8.50	21.71

Table 2: Thoron concentration of all quarter

S.N.	Location names	(C_T) First Quarters Bqm^{-3}	(C_T) Second Quarters Bqm^{-3}	(C_T) Third Quarters Bqm^{-3}	(C_T) Fourth Quarters Bqm^{-3}
1	IQBALPUR	38.89	16.07	25.33	30.44
2	LAKSAR	32.81	16.81	14.67	19.33
3	DEOBAND	20.67	22.30	19.63	11.19
4	NAGAL	31.85	21.48	12.96	28.00
5	GAGALHERI	12.07	18.52	16.44	33.33
6	NANAUTA	16.07	11.19	20.74	21.70

7	SARSAWA	33.19	15.19	28.44	30.30
8	SHERMAU	31.63	18.19	21.93	16.67
9	SHAMLI	19.56	23.48	13.04	23.19
10	TITAWI	13.63	13.48	25.56	36.15
	AVERAGE	25.04	17.67	19.87	25.03
	MAX	38.89	23.48	28.44	36.15
	MIN	12.07	11.19	12.96	11.19
	G.M.	23.22	17.26	19.17	23.72
	S.D.	9.64	3.94	5.52	7.94

Table 3: EERC of all quarter

S.N.	Location names	EERC First Quarters Bqm^{-3}	EERC Second Quarters Bqm^{-3}	EERC Third Quarters Bqm^{-3}	EERC Fourth Quarters Bqm^{-3}
1	IQBALPUR	20.37	6.63	8.58	8.27
2	LAKSAR	22.65	8.27	5.29	15.43
3	DEOBAND	9.51	7.04	7.76	13.70
4	NAGAL	7.02	15.51	3.89	17.24
5	GAGALHERI	3.02	5.70	7.10	12.04
6	NANAUTA	7.88	7.76	6.46	9.28
7	SARSAWA	9.24	5.02	6.67	14.32
8	SHERMAU	13.85	10.16	4.20	11.50
9	SHAMLI	8.60	13.77	8.54	17.59
10	TITAWI	10.72	9.30	8.60	22.20
	AVERAGE	11.29	8.92	6.71	14.16
	MAX	22.65	15.51	8.60	22.20
	MIN	3.02	5.02	3.89	8.27
	G.M.	9.86	8.39	6.47	13.60
	S.D.	6.07	3.41	1.76	4.19

Table 4: EETC of all quarter

S.N.	Location names	EETC First Quarters Bqm^{-3}	EETC Second Quarters Bqm^{-3}	EETC Third Quarters Bqm^{-3}	EETC Fourth Quarters Bqm^{-3}
1	IQBALPUR	2.07	0.76	0.66	0.63
2	LAKSAR	1.12	1.35	0.56	0.91
3	DEOBAND	0.86	0.54	1.15	1.51
4	NAGAL	1.00	0.79	0.58	2.40
5	GAGALHERI	0.31	0.79	0.64	1.26
6	NANAUTA	1.00	0.82	0.72	1.45
7	SARSAWA	0.76	0.65	0.57	1.37
8	SHERMAU	1.38	1.14	0.59	1.92
9	SHAMLI	0.89	1.06	0.82	0.99
10	TITAWI	1.19	0.87	0.75	1.68
	AVERAGE	1.06	0.88	0.70	1.41
	MAX	2.07	1.35	1.15	2.40
	MIN	0.31	0.54	0.56	0.63
	G.M.	0.96	0.85	0.69	1.32
	S.D.	0.46	0.24	0.18	0.51

The evaluation values of Radon, Thoron, and their progeny concentration nearby houses of some sugar mills in Uttara Pradesh and Uttarakhand states of India are tabulated in Tables- 1,2,3, and 4. The radon concentration of the first, second, third, and fourth quarters varied from 18.65 Bqm^{-3} to 83.49 Bqm^{-3}, 19.87 Bqm^{-3} to 36.12 Bqm^{-3}, 19.96 Bqm^{-3} to 46.93 Bqm^{-3}, and 20.13 Bqm^{-3} to 90.98 Bqm^{-3}, with an average of 43.02 Bqm^{-3}, 28.37 Bqm^{-3}, 28.59 Bqm^{-}3, and 45.67 Bqm^{-3}respectively. The values of thoron concentration first, second, third and fourth quarters varied from 12.07 Bqm^{-3} to 38.89 Bqm^{-3}, 11.19 Bqm^{-3} to 23.48 Bqm^{-3}, 12.96 Bqm^{-3} to 28.44 Bqm^{-3}, and 11.19 Bqm^{-3}, to 36.15 Bqm^{-3} with an average of 25.04 Bqm^{-3}, 17.67 Bqm^{-3}, 19.87 Bqm^{-3} and 25.03 Bqm^{-3} respectively. The average values of EERC first, second, third and fourth quarters varied from 3.02 Bqm^{-3} to 22.65 Bqm^{-3} ,5.02Bqm^{-3} to 15.51 Bqm^{-3},3.89$Bqm^{-3}$to 8.60 Bqm^{-3} and 8.27 Bqm^{-3} to 22.20 Bqm^{-3}, with an average 11.29 Bqm^{-3}, 8.92 Bqm^{-3}, 6.71 Bqm^{-3} and 14.16 Bqm^{-3} respectively. The average values of EETC first, second, third and fourth quarters varied from 0.31 Bqm^{-3} to 2.07 Bqm^{-3}, 0.54 Bqm^{-3} to 1.35 Bqm^{-3},0.56 $Bqm^{-3}$to 1.15 Bqm^{-3}, and 0.63 Bqm^{-3} to 2.40 Bqm^{-3}, with an average 1.06 Bqm^{-3} , 0.88 Bqm^{-3} , 0.70 Bqm^{-3} and 1.41 Bqm^{-3} respectively.

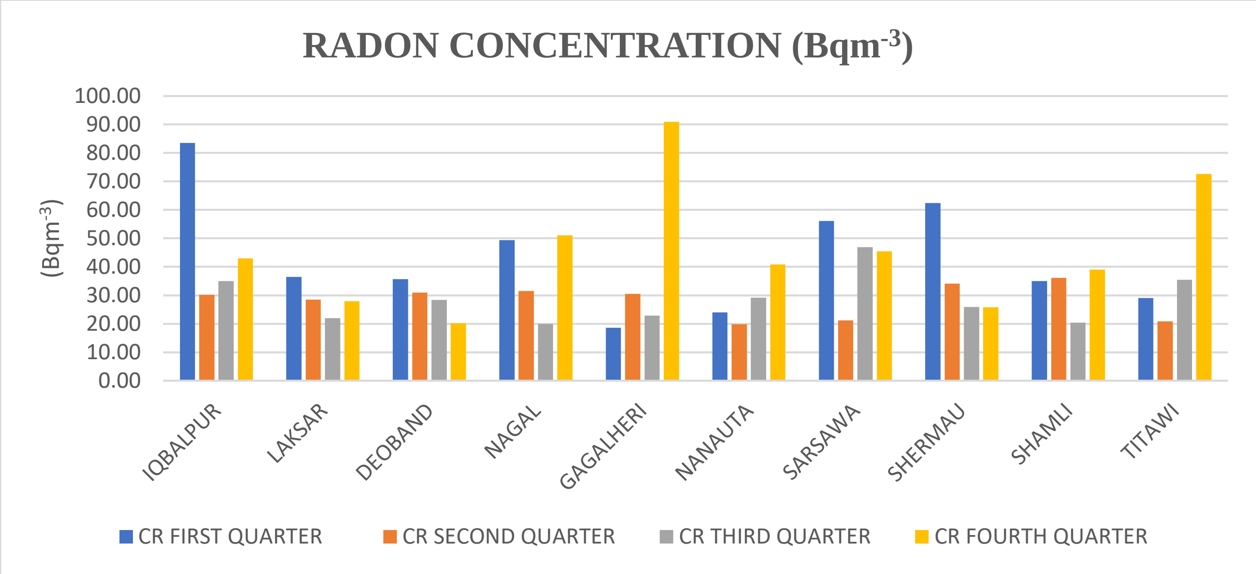


Fig.4:-Radon concentration for all quarters.

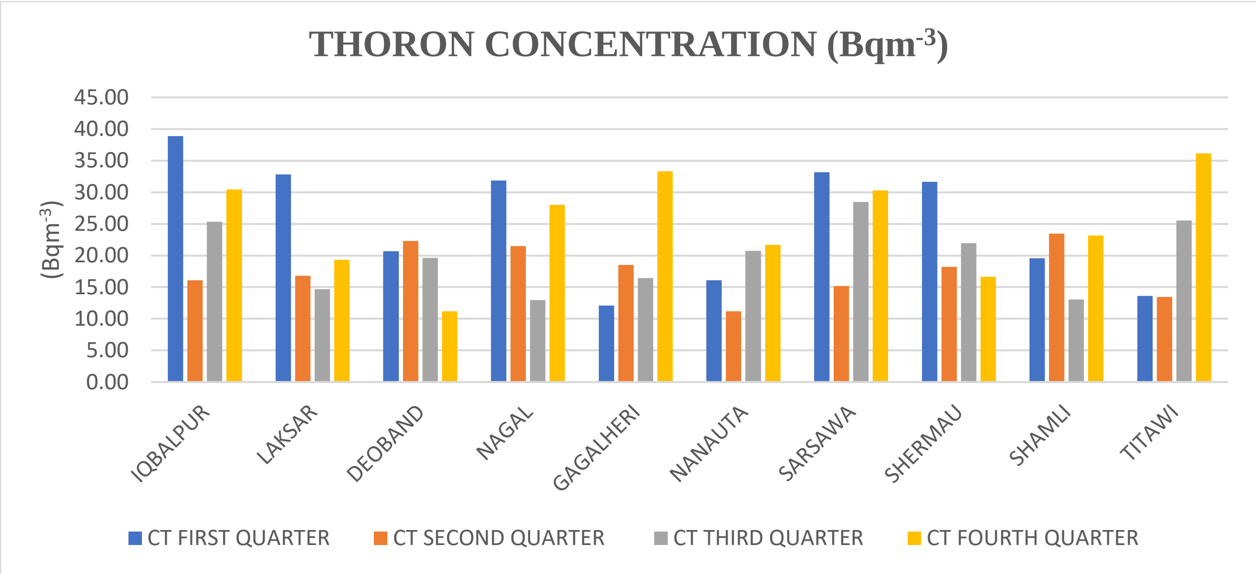


Fig. 5:-Thoron concentration for all quarters.

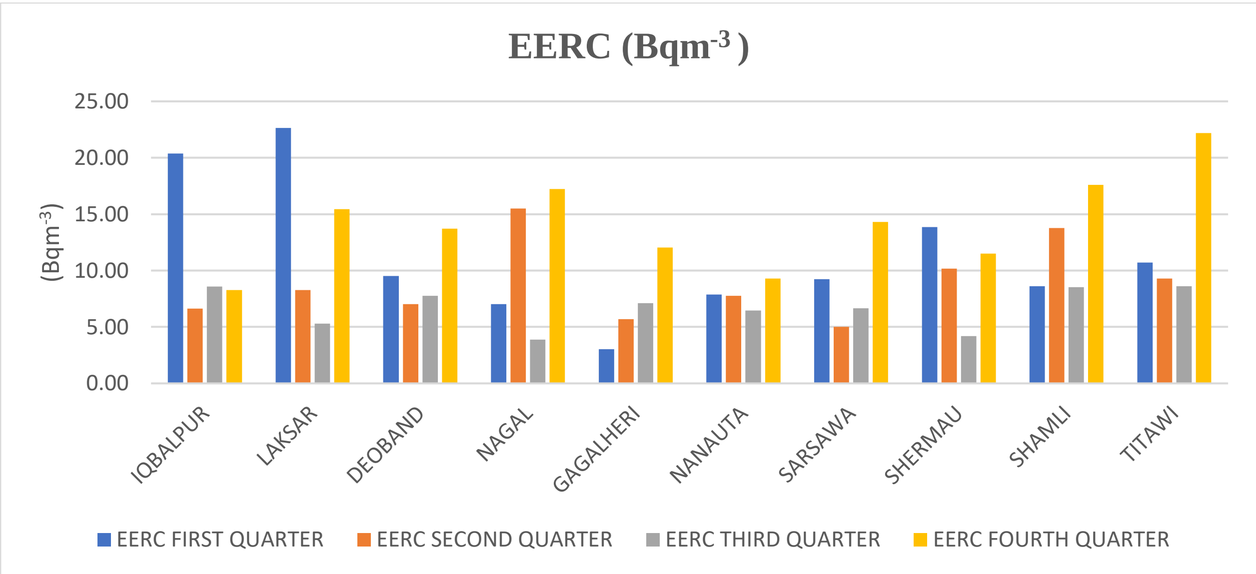


Fig.6:-EERC for all quarters.

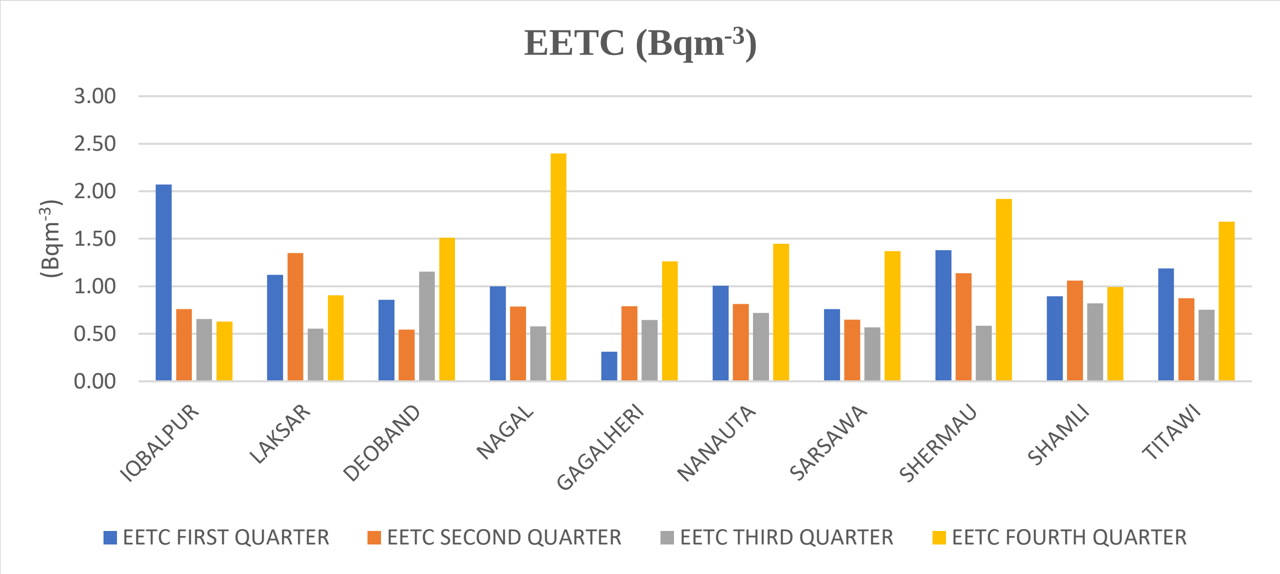


Fig.7:- EETC for all quarters.

In the above figures 4, 5, 6, and 7 show all seasonal values of radon, thoron, EERC, and EETC concentration respectively average values, maxima, minima, standard deviation, and geometry mean. All these values depend on the atmospheric and geological conditions such as air pressure, rainfall and temperature of agriculture cropland, and population activity in Uttara Pradesh and Uttarakhand selected locations. The average values of radon, thoron EERC, and EETC were high in different locations with different quarters in a year Gaglheri fourth quarter radon concentration was higher other than location, and quarters of radon concentration is 90.98 Bqm$^{-3,}$ and Iqbalpur first quarter thoron concentration higher other than locations and quarters of thoron is 38.89 Bqm^{-3}, EERC Lakshar value higher other than locations is 22.65 Bqm^{-3} in first quarter and EETC Nagal location concentration value higher other than location is 2.40 Bqm^{-3}, in a complete year quarters.

Conclusion

In the present study, all data compared by the international UNSEAR data for human living references the level of radon concentration in the environment. All these locations and mills are lower than the standard concentration value. Each location concentration is different with the fluctuation of atmosphere and temperature variation respectively seasons. In each location mills and human houses are between 100 meters to 500 meters but no more effect on the human body because nearby all locations fill natural environments and plants. Similarly, sugar mills smoke no more effect on the trees and land. In these locations, Iqbalpur and Shermau mills plants are the oldest other than study mills. Gagalheri mills are new to other mills in this study.

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