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Distribution Pattern of Radon and Thoron Levels in Some Dwellings of Lakhimpur District, Assam

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ABSTRACT

A study on the level of indoor radon and thoron in some dwellings of Lakhimpur district, Assam has been presented in this communication. A total of twenty houses were selected and analyzed for radon and thoron emission. The implications presented in this paper are based on statistical analyses of the raw data. Normal distribution analysis (NDA) and ANNOVA are employed to find out the distribution pattern and other related information. Differences between mean and median in each case, high standard deviation, significant kurtosis and skewness indicate that radon and thoron emission in the study area exhibit unsymmetrical distribution with a long asymmetric tail, extending either towards higher or lower values with respect to the median. The study establishes the presence of radioactive emission in the dwellings of the district of Lakhimpur.

Key Words: Radon, Thoron, Skewness, Kurtosis.

INTRODUCTION

Radon is a unique natural element in being a gas, noble and radioactive in all of its isotopes. Gases are of special interest, first they are mobile and can carry messages over significant distances within the earth and in the atmosphere and second, because inhalation can be a problem to health. The nobility of radon prevent it from reacting with the medium it permeates. As a result, free radons usually diminish only by its radioactive decay as it moves out of its source. Finally, its radioactivity allows radon to be measured with remarkable sensitivity. For humans, the greatest importance of the radioactivity property of radon is that, in high concentration, it can be a health hazard, a cause of lung cancer [1].

Since radon measurement can be done with remarkable sensitivity, efforts were undertaken to design devices for radon monitoring. One such device is the passive radon-monitoring device based on alpha particle etched track detectors, which are very efficient for the assessment of long-term radon exposure. The potential of radon measurement with these detectors was first recognized by Fleischer et al. (1965). Since then a variety of studies are being conducted with this technique. However, the indoor radon level data for the North Eastern region of India, particularly of the Brahmaputra Valley of Assam is still scanty of literature [2].

Radon moves by two basic ways: diffusion and forced flow. The specific entry rate of ^{222}Rn from soil ranges from 0.5 to 200 Bqm^{-3}h^{-1} resulting in an indoor concentration in the range of 0.5 – 500 Bq ms-pes^{3} [3]. The specific entry from the building materials can range from 1 to 50 Bq m^{-3}h^{-1} resulting in an indoor concentration of 0.7 to 10.0 Bqm^{-3} [4]. The specific entry from other sources including outdoor air, water and natural gases work out to be less than 10% of the rate from the soil and building materials [5]. Thus, there is a natural occurrence of radon in houses. For an individual person exposed to radon gas for a long time, there is from medical point of view an increase in the risk of growth of lung cancer [6], although low dose irradiation lowers the risk of cancer [7].

In this study, efforts are made to estimate the indoor level concentration with the help of Solid State Nuclear Track Detectors (SSNTD) in the dwelling of the district of Lakhimpur. The study area Lakhimpur district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. Geographically, the district lies between $26^{0}48^{/}$ and $27^{0}53^{/}$ northern latitude and $93^{0}42^{/}$ and $94^{0}20^{/}$ eastern longitude (approximately). The district covers an area of 2,977 km^{2} and falls under sub-tropical climatic region, and enjoys monsoon type of climate. A preliminary survey conducted by the author showed the occurrence of lung cancer in the inhabitants of the region whose ages ranged from 16 to 60 years. The study is concerned in finding the indoor radon and thoron levels in various types of houses, namely the RCC i.e. reinforced cement concrete house and the Assam Type (AT) i.e. houses with galvanized iron sheet roof and cement plastered walls with cement flooring) in this region and variation of the indoor radon and thoron level with respect to seasonal variation.

MATERIALS AND METHODS

The detector used for the radon and thoron detection is the Solid State Nuclear Track Detector, which is a passive device for radon detection. The detector employed is LR-115 (Type-II) which are strippable cellulose nitrate film, available from Kodak, placed in twin chamber radon/ thoron plastic dosimeter cup (B.A.R.C. type). The cup unit comprise of a plastic cylindrical vessel of 11 cm in length and 7 cm in diameter opened at both ends. There is a plastic dividing wall in between the cup, which divides the cylinder in to two equal parts of 5.5 cm each. Two detectors are attached on this divider wall so that they remain inside the cup and one detector can be placed at the outer side of the cylinder. One of the two ends of the cups is covered by covered by thoron membrane. The use of this membrane is to exclude condensed alpha emitter. The area and thickness of the membrane is so designed that it excludes unwanted ^{219}Rn (half life 3.96 s) and ^{220}Rn (thoron with half life 55.6s) without unduly diminishing ^{222}Rn (radon with half life 3.82 d), along with the daughters that are produced after ^{222}Rn enters the detection space. This membrane is made of porous material such as fibreglass, micro-porous paper or a plastic such as polyethylene or PVC. It has been estimated that about 98% of radon (^{222}Rn) penetrates, but thoron does not enter the detecting space [8,9].

The other end of the cup is covered by filter paper (Whatman Grade-41, Dia 55mm).. The detector placed in the outer surface of the cup is kept in bare mode. This views a hemisphere of the air which the minimum radius is 9.1 cm, the range of ^{212}Po alpha in air or 6.4 cm, the range of ^{214}Po alpha [10], both of which are the radon progeny. The bare mode records all the tracks due to radon, thoron and their progeny.

The LR-115 (type II) films are cut into 3cm x 3cm pieces and are placed in the dosimeter cup in the three modes: the filter mode, the membrane mode and the bare mode. The plastic twin chamber cups are then installed inside rooms of the houses chosen. In this study, the cups are placed in RCC (ground floor), Assam Type and in mud houses. The detectors are so placed that the minimum distance from the walls and the ceiling are kept at 10cm, and are exposed for 90-95 days after which they are retrieved. The detectors were then etched by chemical method for which a 2.5 N NaOH solution in distilled water was prepared. A magnetic stirrer was used for preparation of uniform solution. The detectors were then dipped in the solution and were fed to the hot air oven for around 90 minutes at temperature of 60^oC. After that, the films were washed in cold running water very carefully to ensure that no trace of the etching solution remains in the detector. The films are then dried and kept for observation. The measurement of the visible track was then performed using a optical microscope under a magnification of 200x.

Mathematical formulation:

Let N be the number of counted tracks and A be the area of the field of view. Then the track density T is given by:

$T= (N\pm\sqrt{N})/ A$, where A is in cm^2 [11]

Now let T_1 and T_2 be the track densities of radon and thoron imprinted on the membrane and filter mode respectively, d the number of days of exposure. Then the concentration of radon and thoron C_R and C_T in Bqm^{-3} is given by Dwivedi et al [12]

$$C_R = T_1/ d K_R \quad (1)$$

$$C_T = T_2/d K_T \quad (2)$$

Where $K_R = 0.020T\ cm^{-2}d^{-1}Bqm^{-3}$ and $K_T = 0.019T\ cm^{-2}d^{-1}Bqm^{-3}$ are the sensitivity factors for the radon and thoron gas in the membrane and filter compartment respectively [13].

RESULTS AND DISCUSSION

Twenty sampling stations were considered for the study as given in Table. 1.

Table 1 Type and numbers of samples

Number of sources	Dwelling Type	
	Assam Type (AT)	RCC
20	10	10

Univariate statistics were used to test distribution normality for radon and thoron. Moment coefficients of skewness and kurtosis were calculated to express how the shapes of sample frequency distribution curves differ from ideal Gaussian (normal). Skewness was calculated as third moment of the population mean. Kurtosis was calculated as fourth moment of the population to describe the heaviness of the tails for a distribution. Some more statistical estimates derived from the normal distribution in the form of Sample variance, 1^{st} , 2^{nd} , 3^{rd} Quartile were also made in the present study to find out the distribution pattern of the data and other related information Details of these may be found in standard books on statistics and software packages [14]. We also ran one-way ANOVA to compare the concentrations of radon and thoron in different seasons. We used an alpha level of 0.05 and considered differences to be significant if $P \leq 0.05$.

Radon level in AT houses:
Various statistical estimates derived from NDA for radon in AT houses of the study area are summarized in Table 2.

Positive skew obtained during Oct-Dec and Jan-Mar shows unsymmetrical distribution of radon with a long right tail with respect to the median. Negative skewness of the data is also indicative of the asymmetric nature of radon distribution during April-June and July-Sept. in the study area. The distribution of radon is also found to be sharp with positive kurtosis values in all the seasons. Differences between mean, median and mode, significant standard deviation and error value indicate that their distribution is widely off normal in AT houses of the study area. ANNOVA analysis (F = 10.84586, p = 3.20686E-5) at the 0.05 level suggests that the means are significantly different in all the seasons.

Table 2 Distribution of radon levels in AT houses

Statistics		Oct–Dec, 08	Jan-Mar,09	Apr-June, 09	July- Sept, 09
Mean		159.7	182.0	121.4	124.8
Std. Error of Mean		9.2	9.4	8.2	8.5
Median		145.4	172.9	124.5	124.1
Mode		121.3(a)	147.8(a)	73.7(a)	77.4(a)
Std. Deviation		29.0	29.6	25.8	27.0
Variance		840.2	878.3	664.8	728.6
Skewness		0.6	0.6	-0.4	-0.3
Std. Error of Skewness		0.7	0.7	0.7	0.7
Kurtosis		-1.1	-1.2	-0.2	-0.5
Std. Error of Kurtosis		1.3	1.3	1.3	1.3
Range		84.1	82.8	85.7	86.3
Minimum		121.3	147.8	73.7	77.4
Maximum		205.4	230.6	159.4	163.7
Sum		1597.0	1819.6	1213.9	1248.2
Percentiles	25	141.7	156.2	99.8	105.1
	50	145.4	172.9	124.5	124.1
	75	192.0	214.7	143.6	150.9

(a) Multiple modes exist. The smallest value is shown

Radon level in RCC houses:
Statistical values for radon in RCC houses of the study area are presented in Table 3. A broad third quartile and positive skewness in case of radon in RCC hoses of the study area represents a long asymmetric tail extending towards higher values with respect to the median. Heaviness of the tail for radon distribution in the area is evident from significant kurtosis values in all the seasons. Wide data range and high standard deviation in case of radon is likely to bias the normal

distribution statistic. ANNOVA analysis (F = 10.77293, p = 3.39143E-5) at the 0.05 level suggests that the means are significantly different in all the seasons.

Table 3 Distribution of radon levels in RCC houses

Statistics		Oct–Dec, 08	Jan-Mar,09	Apr-June, 09	July- Sept, 09
Mean		226.5	231.7	159.0	155.1
Std. Error of Mean		14.1	16.1	9.6	9.8
Median		211.6	214.6	158.4	154.9
Mode		179.8(a)	178.5(a)	117.9(a)	108.6(a)
Std. Deviation		44.6	50.8	30.3	31.1
Variance		1986.8	2583.5	915.9	967.0
Skewness		1.0	1.1	0.5	0.2
Std. Error of Skewness		0.7	0.7	0.7	0.7
Kurtosis		-0.1	-0.2	0.2	-1.0
Std. Error of Kurtosis		1.3	1.3	1.3	1.3
Range		134.6	145.2	99.8	92.7
Minimum		179.8	178.5	117.9	108.6
Maximum		314.4	323.7	217.7	201.3
Sum		2264.8	2317.2	1589.9	1550.9
Percentiles	25	189.1	193.4	136.4	130.6
	50	211.6	214.6	158.4	154.9
	75	268.9	275.8	179.1	180.7

(a) Multiple modes exist. The smallest value is shown

Thoron level in AT houses:

Statistical values derived from NDA for thoron in AT houses of the study area are presented in Table 4.

In all the seasons positive skewness value for thorn indicates an asymmetric tail extending towards higher values. A positive kurtosis value is also indicative of sharp distribution of thoron in AT houses of the area. Analysis of variance (ANOVA) at the 0.05 level suggests that the means for thoron in the area are significantly different (F = 9.00559, p = 1.38936E-4) in all the seasons.

(a) Multiple modes exist. The smallest value is shown

Thoron level in RCC houses:

Statistical data for thoron in RCC houses of the study area are shown in Table 5. Significant differences among mean, median and mode along with significant moment coefficients of skewness and kurtosis obtained for thoron in RCC houses in the area show that sample frequency distribution curves differ from ideal Gaussian (normal). ANOVA analysis at the 0.05 level for thoron suggests that the means in all the seasons are significantly different (F = 6.03551, p = 0.00194).

Table 4 Distribution of thoron levels in AT houses

Statistics		Oct–Dec, 08	Jan-Mar,09	Apr-June, 09	July- Sept, 09
Mean		28.2	28.0	17.9	17.0
Std. Error of Mean		2.3	1.9	2.2	1.7
Median		26.2	27.1	16.3	15.6
Mode		19.80(a)	23.50(a)	11.70(a)	11.80(a)
Std. Deviation		7.3	6.0	6.9	5.5
Variance		53.2	36.6	47.2	30.5
Skewness		1.3	1.8	2.2	1.8
Std. Error of Skewness		0.7	0.7	0.7	0.7
Kurtosis		1.2	4.0	6.0	3.8
Std. Error of Kurtosis		1.3	1.3	1.3	1.3
Range		23.8	21.4	24.1	18.7
Minimum		19.8	21.4	11.7	11.8
Maximum		43.6	42.8	35.8	30.5
Sum		282.0	279.8	179.1	170.4
Percentiles	25	23.2	23.5	13.3	13.0
	50	26.2	27.1	16.3	15.6
	75	31.7	30.5	19.2	20.0

(a) Multiple modes exist. The smallest value is shown.

It is seen from the study that radon concentration varies from 121.4 to 182.0 BqM^{-3} in AT houses (i.e. houses with galvanised iron sheet roof and cement plastered walls with cement flooring), from 151.1 to 231.7 BqM^{-3} in RCC houses (i.e., reinforced cement concrete house). There is also a considerable change in radon emission with season: higher concentration in winter. The variation of thoron concentration also shows similar distribution: highest in RCC houses and during winter season. These variations can be attributed to the following causes:

1. During winter, the ventilation of the houses is poor due to which the radon filled air could not ventilate out properly.
2. The building materials may be a prime source of radon and a RCC house requires much more building material compared to an AT house of same area.

These conclusions also agree with the literature [15]. Further higher concentration of radon can also be attributed to the soil and rock type in which the houses are located. Study involving this aspect is likely to be initiated in near future.

Table 5 Distribution of thoron levels in RCC houses

Statistics		**Oct–Dec, 08**	**Jan-Mar,09**	**Apr-June, 09**	**July- Sept, 09**
Mean		38.5	39.9	19.0	18.4
Std. Error of Mean		5.9	5.9	3.5	3.4
Median		30.7	30.9	14.4	13.5
Mode		19.40(a)	21.30(a)	10.70(a)	9.40(a)
Std. Deviation		18.6	18.7	11.0	10.7
Variance		345.3	351.6	120.7	115.2
Skewness		1.1	0.9	2.0	1.6
Std. Error of Skewness		0.7	0.7	0.7	0.7
Kurtosis		-0.4	-1.1	3.9	1.9
Std. Error of Kurtosis		1.3	1.3	1.3	1.3
Range		53.2	50.3	35.2	33.1
Minimum		19.4	21.3	10.7	9.4
Maximum		72.6	71.6	45.9	42.5
Sum		385.4	399.2	189.9	184.3
Percentiles	25	26.1	25.4	13.0	11.3
	50	30.7	30.9	14.4	13.5
	75	57.1	63.0	23.7	24.3

CONCLUSION

A comprehensive study of radon and thoron emission levels in some dwellings of Lakhimpur district has been carried out. This study establishes the presence of radioactive emission in the dwellings of the district of Lakhimpur. Statistical observations show that radon and thoron concentrations in AT and RCC houses of the study area exhibit an asymmetric distribution with a long asymmetric tail either on the right or left of the median. The width of the third quartile was consistently found to be more than the second quartile for each parameter in all the seasons. Wide data range in each case indicates the presence of extreme values in the form of outliers, which are likely to bias the normal distribution statistic. The concentrations of thoron in the area are either low or moderate. A sizeable number of RCC houses contain radon at an alert level. Thus, efforts should be made to restrict the radon emission in houses of the area by choosing the housing materials as per the international recommendations.

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