Estimation of indoor radon levels and their progeny using SSNTD LR115 (type -II) detector in Oil Field Areas of Upper Assam

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Abstract: In this investigation, Indoor Radon and Thoron Concentrations, the activity levels of Indoor Radon Progeny Levels, Thoron Progeny Levels and Annual Effective Inhalation Dose have been reported for different houses of Upper Assam mainly in oil field areas. BARC Twin cup dosimeters were deployed in the studied locations and LR-115(type II) solid state nuclear track detector was used to measure radon and thoron concentration level. The measurements have been carried out in fifteen dwellings of three different districts situated in and around the oil fields of upper Assam region. The indoor radon and thoron progeny levels as well as their concentrations with effective inhation doses are found maximum in RCC types of houses than Assam type of houses. The average indoor radon concentration varies from 168.5 Bq/m^3 to 291.5 Bq/m^3 for RCC houses where in AT type houses it varies from 81.7 Bq/m^3 to 85.9 Bq/m^3 whereas the thoron concentration varies from 12.58 Bq/m^3 to 26.24 Bq/m^3 in RCC type houses and it varies from 6.53 Bq/m^3 to 7.60 Bq/m^3 in AT type houses. The average effective inhalation dose in dwellings of different houses varies from 0.24 mSv/y to 0.32 mSv/y that lie within the safe limit recommended by ICRP, 2011 & ICRP, 1993) .

IndexTerms **-** Indoor radon, Progeny, LR-115, Effective Inhalation Dose.

I. INTRODUCTION

Radon (^{222}Rn), a unique natural element and radioactive gas which is formed naturally by the breakdown of Uranium which is found in soil and some building materials (soil, rocks and water all over the earth). Radon in soil is the main source of indoor radon (Al-Khateeb ,H.M., Aljarrah,K.M, Alzoubi,F.Y, Alqadi,M.K.,& Ahmed,A.A.)in the earth's atmosphere. Among three natural isotopes of radon, the isotope ^{222}Rn is responsible for approximately half of the effective dose received by the population from natural radiation sources because it has a half-life (3.82 days) which is much greater than that of ^{220}Rn (55.6 s) and ^{219}Rn (3.92 s) (Milic,G., Gulan,L., Bossew,P., Vuckovic,B., & Zunic,Z.S., 2013) and it is neglected. When radon gas is inhaled, it leads to DNA damage in the lung(Edling.J.,Sevc,.C) because highly ionizing alpha particles emitted from short-lived decay products of radon (^{218}Po and ^{214}Po) can interact with biological tissue in the lungs leading to DNA damage causes cell mutation and results into lung cancer(Edling,C.,Wingreen,G.,Axelson,O.,;Sevc,J.,Kunz,E.,&Placek,V.;Bochicchio,F.,Forasiere,F.,Abeni,D.,&Rapit,E.).Therefore, considerable attention has been paid to measure the concentration of indoor radon in buildings in the last three decade (UNSCEAR, 2000, Dey G.K, Das P.K,2012).Also It has been reported that the indoor radon as well as thoron progeny levels in RCC types of houses are more than in Assam type houses(Deka P.C.,Bhattacharjee B., Sarma B.K. and Goswami T.D.) in some areas of Assam. The correlation between long term exposure to high concentration of radon and lung cancer (Archer,D.B., Pershagen, G.) and kidney diseases(Waxweiler T.V.) has been established. Different types of dwellings have been reported by many research workers which shows the existence of radon and thoron (Ramsiya, M.,Antony,J.&Jojo,P.J&Mishra,R.,Tripathy,S.,Pachuau,L.,Laldawnglina,C). Though the radon levels in the places measured already is well within safety limits, considering the growth of industrialisation and urbanisation, it becomes more important to take further studies for effective radon exposure in the studied area. Keeping in view of the importance of the study of radon levels in this present investigation, the oil field areas of upper Assam has been selected for carrying out study of the radon and thoron progeny levels as well as their concentrations in both RCC and AT houses.

II AREA UNDER INVESTIGATION

Assam is rich in a number of minerals like crude oil, natural gas, coal, iron ore having major reserves of oil and gas. In the present study, effort has been made to estimate the indoor radon / thoron levels in some of the Reinforced cement concrete (RCC) types of houses as well as Assam Type (AT) houses in Upper Assam in and around oil field area which are Tinsukia district, Dibrugarh district and Sivasagar districts of Assam, India. Geographical location of the area from 26090′11.5″N to 27^{0}36′18.3″ N latitude and 94^{0}36′10.6″E to95^{0}32′23.6″E . The studied locations have been marked by arrow in the map as shown in figure 1.

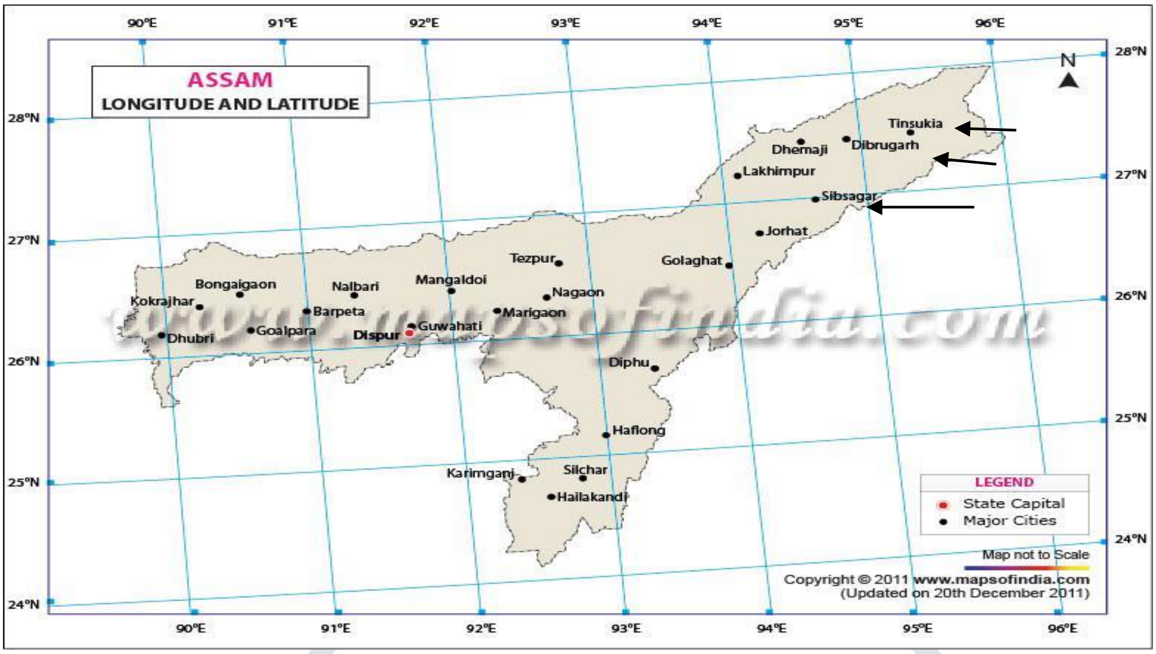


Fig.1. Map of Assam showing Dibrugarh district, Tinsukia district and Sivsagar district.

III. METHODOLOGY

Solid State Nuclear Track Detector (LR-115) was used in this study to estimate the levels of radon gas concentration in the environs of the studied area..In this study, a sheet of LR-115(type II) detector was cut into pieces of about (1 × 1 cm^2), the detector was inserted into a BARC twin cup dosimeter. the open end of the cup covered with a filter paper to keep the dust particles outside the cup allowing radon gas ^{222}Rn to enter the cup freely, as well as the filter acts to delay the two isotopes ^{220}Rn and ^{219}Rn which allowing them to decay before reaching the detector at the bottom of the cup (Abu-Jarad,F., Fazal-ur-Rehman,X. & Al-Shukri,A.), then the cups were distributed in different locations of oil areas in upper Assam. The cups were placed for 3 months in all locations and the detectors were placed for one whole year quarterly basis as per seasonal variation.

After three-months of exposure, LR-115 detectors were collected and etched together for 90 minutes in 2.5 N NaOH solution and solution is at constant temperature (60±1)°C, with accuracy ± 1 °C for chemical etching (Hesham H.A, ; Zarrag, El-Araby,E.H. & Elhaes,H.). The detectors were then removed from the etching solution, washed with distilled water and dried. The alpha tracks density were counted manually for each detector using the optical microscope of 400 x magnification power attached to a video camera via a numerical interface card with the PC and specified software (ArcSoft WebCam Companion). An unexposed sample of the LR-115 was also etched and scanned for the determination of background track density of the sample. This background track density was found to be very small and was subtracted from the observed value of the readings. The radon and thoron concentrations (C_R, C_T) Bqm^{-3} are given by the following equations.

$$C_R = \rho_m / K_{rm}\, T \quad \ldots\ldots(1)$$

$$C_T = \rho_f / K_{tf}\, T - K_{rf}.\, C_R / K_{tf} \quad \ldots\ldots(2)$$

where ρ_m and ρ_f are the track densities (tr.cm^{-2}) in membrane mode and filter mode respectively. T represents the exposure period in days. The calibration factors K_{rm}, K_{rf} and K_{tf} were determined experimentally by exposing the dosimeters to known concentrations of radon, thoron and their progenies using standard sources. These were compared with the theoretically computed values (Eappen & Mayya, 2004). The calibration factors used in this experiment are shown below.

$$K_{rm} = 0.019 \pm 0.003 \text{ tracks } cm^{-2}d^{-1} .\ Bqm^{-3}$$

$$K_{rf} = 0.020 \pm 0.004 \text{ tracks } cm^{-2}d^{-1} .\ Bqm^{-3}$$

$$K_{tf} = 0.016 \pm 0.005 \text{ tracks } cm^{-2}d^{-1} .\ Bqm^{-3}$$

The progeny working levels (Potential Alpha Energy Concentration-PAEC) were calculated using the formula (Khan, D., Khan, S.).

$$Cp = C\, xF / 3.7 \quad \ldots\ldots(3)$$

where F is the equilibrium factor and it is 0.4 for radon and 0.1 for thoron assessment(ICRP,2011& UNSCEAR,1999) .C stands for radon or thoron concentration. The annual Effective Inhalation Dose (EID) was calculated using the formula (ICRP, 1993)

$$EID(R) = EEC(R).DCF(R)).OF \quad \ldots\ldots(4)$$

$$EID(T)= EEC(T).DCF(T).OF \quad \ldots\ldots(5$$

where EEC(R) and EEC(T) are the equilibrium equivalent concentration of radon and thoron respectively.

Now,

$$EEC(R)= F.C_R \quad \ldots\ldots(6)$$

$$EEC(T)= F.C_T \quad \ldots\ldots(7)$$

DCF(R) (9 $nSvh^{-1}\ Bq^{-1}\ m^3$) and DCF(T) (40 $nSv\ h^{-1}\ Bq^{-1}\ m^3$) are the radon and thoron dose conversion factors and OF (7000 h) is the occupancy factor, i.e. hours of indoor air exposure per year respectively as recommended by UNSCEAR (Mayya, Y.S., UNSCEAR,2008).

AbbreviationsandAcronyms

EID= Effective Inhalation Dose

DCF=Dose Conversion Factor

OF=Occupancy Factor

EEC=Equilibrium Equivalent Concentration

UNSCEAR=United Nations Scientific Committee on the Effects of Atomic Radiation

ICRP=International Commission on Radiological Protection

IV. RESULTS AND DISCUSSION

The indoor radon levels in different oil area in and around of upper Assam are studied by SSNTDs (LR-115, Type II) in Plastic Twin Chamber dosimeter cups for one full calendar year (2016-17) .The study was taken over in four quarters to study the seasonal variations are given in table 1and table 2. From this study , it has been found that the mean indoor radon concentration varies from 189.47 Bq.m^{-3} to 208.69 Bq.m^{-3} with a mean value 13.68 Bq.m^{-3} for RCC houses and 4.88 Bq.m^{-3} to 5.09 Bq.m^{-3} for AT houses and that of indoor thoron concentration varies from 11.13 Bq.m^{-3} to 24.64 Bq.m^{-3} with a mean value 17.88 Bq.m^{-3} for RCC houses and 6.32 Bq.m^{-3} to 7.55 Bq.m^{-3} for AT houses with a mean value 6.93 Bq.m^{-3}. The mean indoor progeny level varies from 11.63 mWL to19.92 mWL for RCC houses and 5.1 mWL to 5.68 mWL and for thoron progeny level varies from 0.15 mWL to 0.89 mWL for RCC houses and for AT houses it varies from 0.15 mWL to 0.19 mWL .The value of annual effective inhalation dose for radon in RCC and AT type houses are 2.01 μSv.h^{-1} and 0.79 μSv.h^{-1} and for thoron it is 0.28 μSv.h^{-1} and 0.18 μSv.h^{-1} . These values are two or three times greater than that of world average of 40 Bq.m^{-3} (UNSCEAR , 2000). This may be due to the difference in the concentration of radioactive elements viz. uranium and radium in the soil and building materials of the study area. However these values are less than the lower limit of action level recommended by (ICRP,1993)

The measurements of indoor radon progeny levels, indoor radon concentrations and thoron concentration with EID values for Radon and Thoron in different types of houses are given in the table 1 and 2. The recorded mean radon/thoron and their progeny levels are maximum in the months from December 2017 to March 2018 i.e. during winter season. This may be due to the fact that during winter, most of the day doors and windows are remained closed. Again the radon/thoron progeny level and radon / thoron concentrations are higher than in RCC type houses than in AT type houses.

Table 1: Measurement of Radon progen levels, thoron progeny levels, radon concentration,thoron concentration, EID for radon and thoron in different types of dwellings of Upper Assam

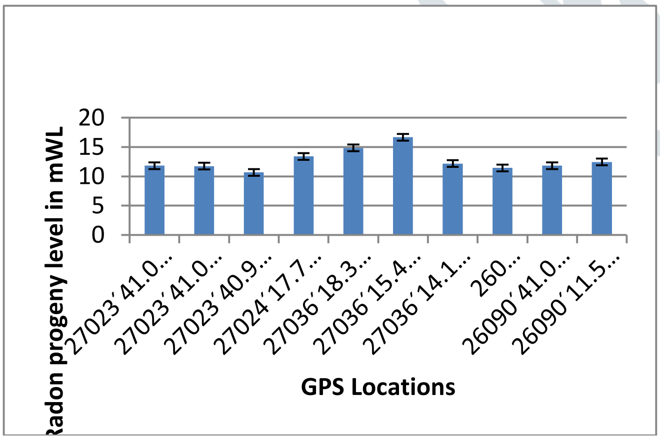
Types of houses	GPS co-ordinates of study locations	Mean Radon progeny level in mWL	Mean Thoron progeny level in mWL	Mean Radon concentration in Bq/m^3	Mean Thoron concentration in Bq/m^3	Mean EID (RADON) in μSv.h^{-1}	Mean EID (THORON) in μSv.h^{-1}
RCC	**27^{0}23´41.0´´N &95^{0}36´10.6´´E**	11.81±0.01	0.68±0.03	198.03±0.05	26.24±0.07	1.87±0.10	0.43±0.59
	27^{0}23´41.0´´N &95^{0}36´10.6´´E	11.75±0.01	0.48±0.05	225.8±0.05	18.69±0.04	1.86±0.12	0.29±0.12
	27^{0}23´40.9´´N &95^{0}36´11.2´´E	10.67±0.01	0.43±0.04	175.9±0.03	15.82±0.05	1.69±0.11	0.25±0.03
	27^{0}24´17.7´´N &95^{0}36´14.4´´E	13.41±0.03	0.51±0.02	169.1±0.01	15.11±0.03	2.56±0.18	0.28±0.06
	27^{0}36´18.3´´N &95^{0}31´16.5´´E	14.84±0.01	0.44±0.01	291.5±0.04	16.04±0.02	2.26±0.16	0.25±0.03
	27^{0}36´15.4´´N &95^{0}36´17.2´´E	16.69±0.02	0.33±0.02	262.03±0.02	12.58±0.04	2.32±0.21	0.21±0.03
	27^{0}36´14.16´´N &95^{0}37´03.16´E	12.17±0.01	0.39±0.03	230.66±0.03	17.85±0.04	1.91±0.12	0.24±0.11
	26^0 90´14.5´´N &94^{0}72´10.6´´E	11.41±0.01	0.53±0.03	239.2±0.04	15.00±0.05	1.82±0.11	0.28±0.11
	26^{0}90´41.0´´N &94^{0}66´16.1´´E	11.81±0.02	0.38±0.05	177.4±0.05	13.85±0.05	1.86±0.11	0.18±0.09
	26^{0}90´11.5´´N &94^{0}36´10.6´´E	12.46±0.01	0.48±0.07	168.5±0.05	17.25±0.05	1.97±0.13	0.24±0.03
	27^{0}36´17.4´´N &95^{0}31´17.2´´E	4.90±0.03	0.16±0.05	81.7±0.02	6.49±0.02	0.77±0.02	0.18±0.06

AT	**27^{0}36´14.16´´N &95^{0}32´03.16´E**	5.01±0.03	0.19±0.04	83.5±0.04	6.99±0.03	0.78±0.01	0.11±0.08
	26^{0}90´14.5´´N &94^{0}35´10.6´´E	5.01±0.05	0.17±0.03	85.1±0.03	6.79±0.03	0.79±0.01	0.11±0.09
	26^{0}90´41.0´´N &94^{0}36´16.1´´E	5.07±0.04	0.20±0.01	82.79±0.03	7.60±0.02	0.79±0.00	0.11±0.08
	27^{0}24´14.5´´N &95^{0}36´10.6´´E	5.11±0.02	0.17±0.03	85.9±0.02	6.53±0.06	0.81±0.01	0.10±0.07

Table2: Measurement of Mean Radon and Thoron levels, Mean Radon and Thoron concentrations and Mean EID for both Radon and Thoron in different seasons

Season	Mean Radon Level		Mean Thoron Level		Mean Radon Concentration		Mean Thoron Concentration		Mean EID for Radon		Mean EID for Thoron	
	RCC	AT	RCC	AT	RCC	AT	RCC	AT	RCC	AT	RCC	AT
Dec 2017-March2018	15.90	5.73	38.8	0.19	240.60	94.1	13.30	7.41	2.44	0.89	0.24	0.28
March2018-June2018	11.93	4.78	36.8	0.16	198.2	79.8	18.36	6.49	1.93	0.75	0.32	0.10
June2018-Sept2018	10.09	4.74	50.3	0.20	172.1	78.9	14.11	7.82	1.60	0.77	0.31	0.12
Sept2018-Dec2018	12.32	4.89	46.6	0.14	221.5	83.7	14.79	5.48	2.07	0.77	0.26	0.09

Fig1: variation of radon progeny level (RCC) Fig2: Variation of radon progeny level with place (AT)



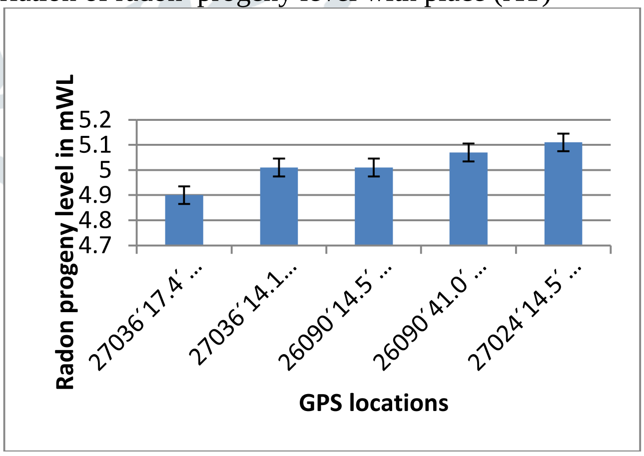


Fig3: Variation of thoron progeny level(RCC)

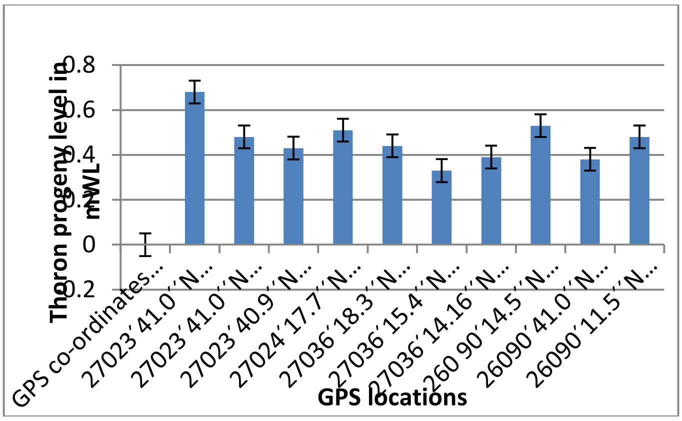


Fig4: Variation of thoron progeny level(AT)

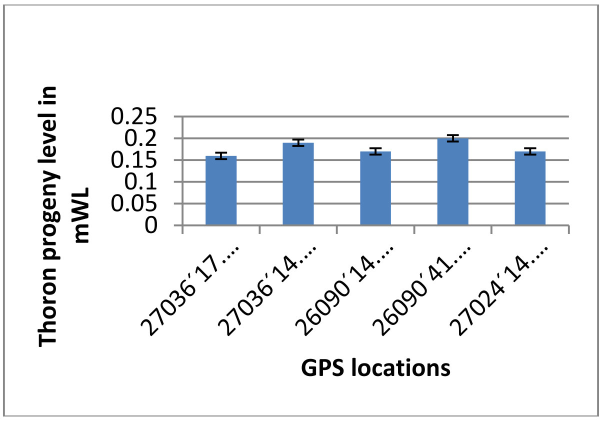


Fig 5: Variation of radon concentration (RCC)

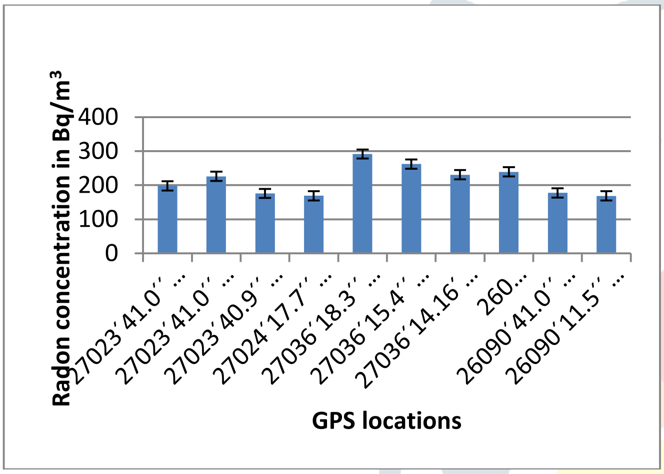


Fig6: Variation of radon concentration(AT)

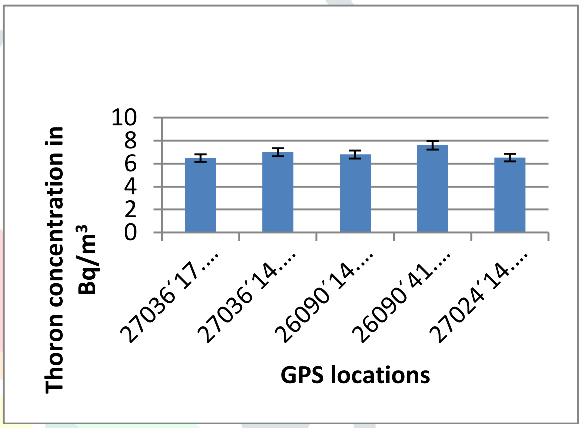


Fig 7: Variation of thoron concentration (RCC)

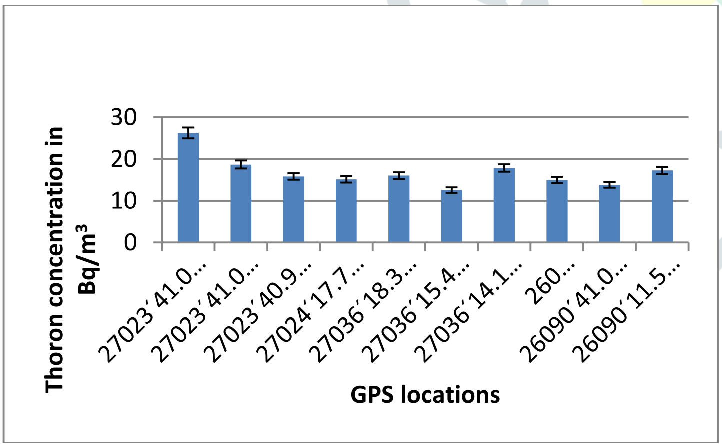


Fig8: Variation of thoron concentration(AT)

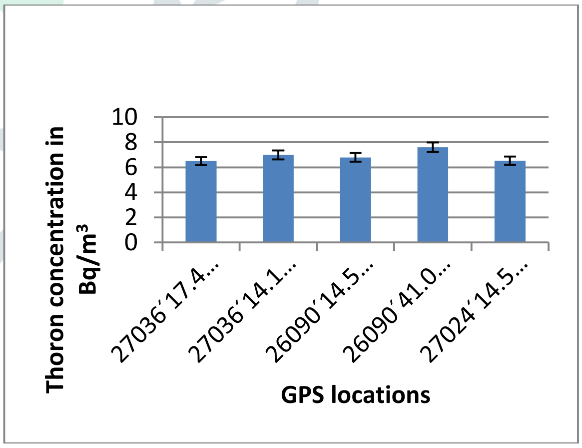
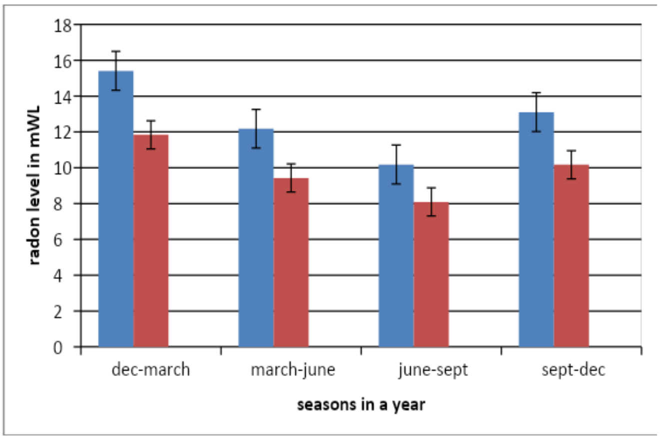
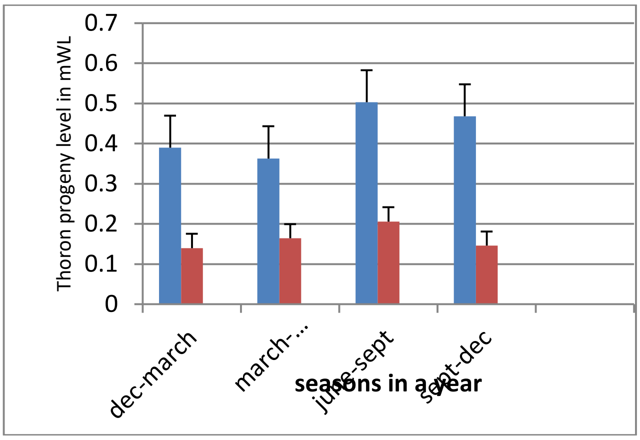


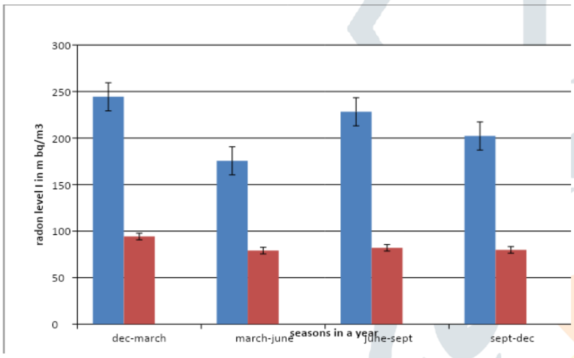
Fig9: Variation of radon progeny level with season Fig10: Variations of thoron progeny Level with season

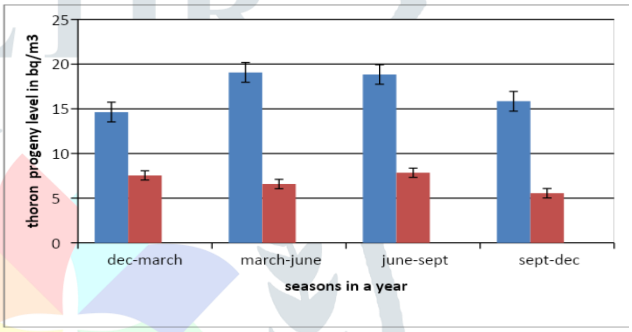




RCC —■ AT —■

Fig3: Variation of radon concentration Fig4: Variation of thoron concentration





V. CONCLUSIONS

From the above study it has been found that the mean radon levels in RCC type of houses are more than in the AT type houses of the studied area and the radon progeny level is more in RCC types of houses than in AT houses. It has been found that the thoron progeny level is also more in RCC types of houses than in AT types houses. Effective inhalation dose for radon is more in RCC than in AT types of houses. Whereas for thoron EID is more in RCC than in AT type of houses. All data from the observations show that indoor radon and thoron level as well as concentrations are more in winter seasons than in other seasons. The high level of indoor radon and thoron during winter may be due to the reason that during winter season doors and windows are closed in most of houses. Another reason may be due to the building materials of construction of different dwellings of the studied locations.

In the studied region, the average indoor radon concentrations as well as annual effective dose rate are found to be below the action level recommended by ICRP. The geometric mean value of radon (209.9 Bqm^{-3}) and thoron (83.57 Bqm^{3}) are higher than the nationwide average value. The estimated inhalation dose varied from 0.37 $mSvy^{-1}$ to 1.99 $mSvy^{-1}$ for radon and 0.07 $mSvy^{-1}$ to1.41 $mSvy^{-1}$ for thoron levels which are below the action level limit (3 $mSvy^{-1}$ to 10 $mSvy^{-1}$) recommended by International Commission on Radiological Protection(ICRP). Based on the results obtained in this present investigation , it may be concluded that the dwellings of the studied locations are safe from environmental hazardness.

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