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Estimation of Annual Effective Dose of 222 Rn and 220 Rn in indoor Air of Rohilkhand region, Uttar Pradesh state, India

Rastogi, N.*, Singh, I. and Goswami, V.

Department of Physics, School of Sciences, IFTM University, Moradabad, UP, India., 244001.

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ABSTRACT: The annual exposure to indoor radon and thoron imparts a major contribution to inhalation doses received by the public. In this study, we report results of time integrated passive of indoor radon and thoron concentrations that were carried out in Rohilkhand region with health risk to the dwellers in the region. In present study, Solid State Nuclear Track Detectors (SSNTDS) based twin chamber dosimeter with LR-115 track detector were used for estimating Radon (^{222}Rn) and Thoron (^{220}Rn) gas concentration levels in the dwellings of Moradabad city. The average Radon and thoron concentration levels in the studied dwellings were found to vary from 13.5 to 21.8 Bq m^{-3} and thoron concentrations is found to vary from 11.7 to 19.5 Bq m^{-3} and its corresponding geometric mean of equilibrium-equivalent ^{222}Rn and ^{220}Rn concentration were found 7.07 to 1.7 Bqm^{-3} . The total annual effective dose due to the exposure to radon and thoron was found to vary from3.7 to 6.2 mSv/y whereas from thoron found to vary from 0.3 to 0.61 mSv/y.

Keywords: Radon, Thoron, Double Dosimeter Cup, LR-115 type-II plastic track detector, SSNTDs.

INTRODUCTION

Environmental pollution has been a great threat to humanity since the beginning of life on earth. So it is natural for us to be active and sensitive against all the pollutants causing threats to our lives (Nasir et al., 2012). The exposure is due to the emanation of radon and thoron gas from the decay chains of radioactive thorium (232 Th) and uranium (238 U) (Kobeissi et al., 2014), which are present in soil layers and indoor construction materials especially granite. Radon is one of the most dominant natural radionuclide in the most environments, and is generated from the decay product of Uranium (238U, 235U) and Thorium (232Th). It is colorless and odorless radioactive noble gas, so easily released through the ground surface (Health Protection Agency, RCE-11, 2009). The half-life of radon 222 and thoron is 3.82 days and 56 seconds respectively that emissions from water, soil and stones. According to the information provided by the National Radiation Protection Board (NRPB), 85% and 15% of the effective doses by human are from the natural and synthetic (man-made) exposures, respectively. The radon and thoron are emitted by the granite stones, black cements (Folkerts et al., 1984) or the content of uranium 238 and thorium 232 (Ramachandran et al., 1989 & Turhan et al., 2012) respectively. The alpha radiation

* Corresponding Author, Email: nikhilrastogi@iftmuniversity.ac.in

emitted from Radon 222 & its daughters (218Po and 214Po) and thoron in the long term can damage the DNA of pulmonary cells and eventually causes lung cancer in human (Taylor-Lange et al., 2012). The World Health Organization has approved the direct significant association of prevalence of lung cancer and radon indoor air. Environmental Protection Agency (EPA) has announced nearly 21000 people deaths due to indoor air radon that is 10 times higher than the mortality rate of air pollution. The global mean concentration of radon in the air inside and outside are 48 $Bq/m^3$and 15 Bq/m^3, respectively. In indoor air, EPA and WHO proposed the standard concentration of radon 148 Bq/m^3 and 100 Bq/m^3, respectively (Topçu et al., 2013). Some other studies show that granite stones emission more radon relative to the other building materials (Farid, 2012). All building materials have radioactive materials although in small amounts. The concentration of radon indoor mainly depends on the emission from building materials, surrounding soils and water resources. In the present study, it was tried to compare the effective doses of radon and thoron in black cement warehouses and stone masonry workshops (mainly granite) in the rohilkhand region of Uttar Pradesh.

Different sources are responsible for the presence of radon and its daughters in houses. The cracks in walls, floors, joints or pipe holes and lines provide a channel for radon which flows to the surface and ultimately enters houses. In addition, the radon production rate in houses depends on the concentrations in the building materials, subsoil, and porosity, density of the uranium and radium activity in materials used for construction (Cartwright et al., 1978).

The concentration of indoor radon & thoron and its progeny also depends on the ventilation rate of the dwellings. It is important that a reduced ventilation rate helps enhance the concentration of radon & thoron and its progenies in the air. The track etch technique is recognized as the most reliable for the integrated and long–term measurement of indoor radon and thoron (Jarad et al., 1981). Most of our time is spent indoors; therefore, the measurement of radioactive gases concentrations in buildings are important (Risica, et al., 1998; Hamori et al.,2004)

The internal exposure occurs through the inhalation of radon gas and external exposure occurs through the emission of penetrating gamma radiation. It is supposed that the health effect of inhabitants is negligible due to the inhalation of radon & thoron and its progeny but recent studies in many countries have shown that this may not be completely correct. People spend about 80% of their time in homes or offices. Therefore the precaution is needed. Several scientist and research workers are engaged in the measurement of radon & thoron and its progeny by using LR-115 type II plastic track detectors in the environment. Ionizing radiation of the environment is the most ubiquitous form of exposure therefore determination of health risk of background gamma radiation is of great importance in health physics (UNSCEAR 2010). In the rohilkhand region, Moradabad city suffers from pollution being producer of different kind of brass products and known as brass city. Therefore the motivation of our study is the possible health risk assessment, due to the radon & thoron and its short lived decay products in inhalation.

In India many research workers are engaged in the measurement of indoor radon thoron and its progeny levels in dwellings and drinking water for health risk assessments and its control (Mehra et al., 2006; Kumar et al., 2012)

The present study was carried out in Rohilkhand region, India. It lies between 28^0 20' and 29^0 16' north latitudes and $78^0$24' and 79^0 0' east longitudes (Rastogi et al., 2017). The measurement of environment indoor radon & thoron and their progeny were made in houses of rohilkhand region of Uttar Pradesh Fig.1. The houses in study area are well, as well as poorly ventilated. The buildings are constructed of concrete, cement, bricks and blocks. Some houses, having glass doors and glass windows are also included in the study.

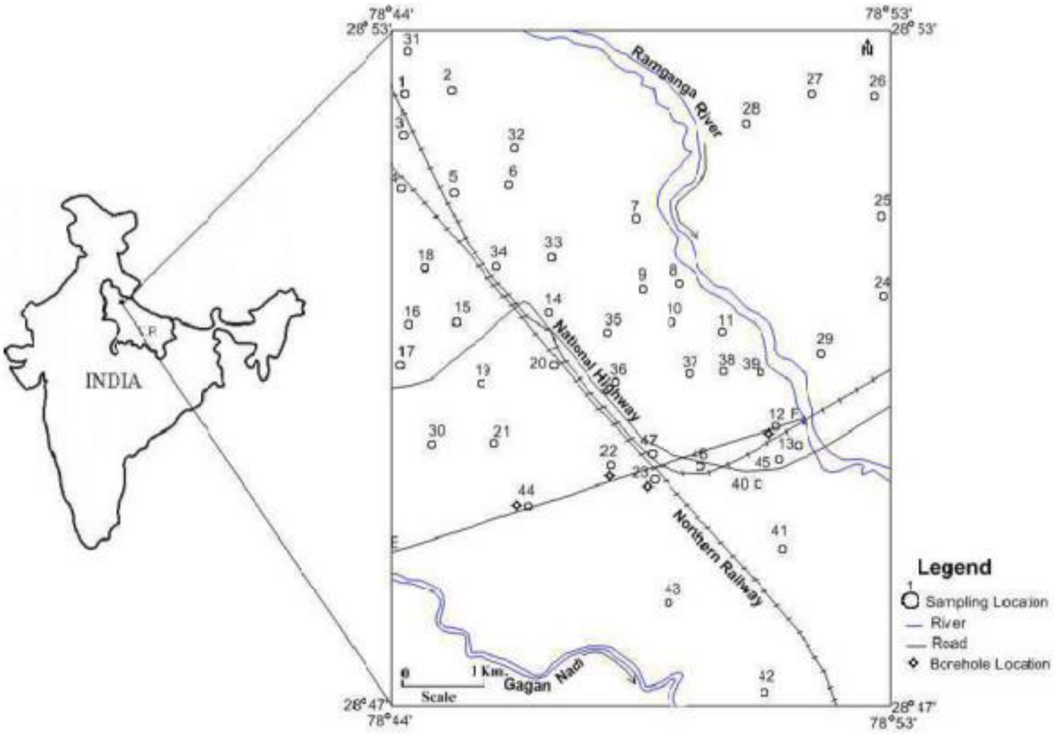


Fig. 1. Map showing sampling location in the area

MATERIAL AND METHODS

The estimation of indoor radon, thoron, and their progenies were carried out using the LR-115 type II plastic track detector loaded in twin-chamber plastic dosimeters (Eappen et al., 2004) Fig-2**.** The detector was placed in a chamber covered with membrane registered tracks only due to radon; the detector was placed in a chamber covered with filter paper registered tracks due to radon and thoron (Mayya et al., 2004). The dosimeters were suspended inside the selected house at a height of about 1 meter from the floor. The detectors were removed and etched using 2.5N NaOH solution at 60°C for 90min. The tracks density was counted using an optical microscope at 400× magnification (Mehra et al.,2013) The registered tracks were counted using a spark counter (Singh et al. 2003). The track densities were calculated from the registered track count and area of the exposed film. The minimum detectable limits for radon and thoron were 5 and 1 Bq/m^3, respectively, whereas for radon-thoron progenies, it was 0.6 mWL. After drying the detectors are ready to count under an optical microscope for track density measurements. The measured track densities for indoor radon and progeny were then converted into Working Levels (WL) and activity concentrations (Bq/m^3) using the following calibration factors used by (Ramola et al. 1996, 1997, 2005) & Rastogi et al., 2017).

125 tracks $cm^{-2}.\ d^{-1}$ =1 WL 3.12x10^{-2} tracks $cm^{-2}\ d^{-1} = 1\ Bq/m^{3}$

Fig. 2. Single entry pin-hole Twin Cup Dosimeter

RESULTS AND DISCUSSION

Observed values of radon and thoron concentration from different location in rohilkhand region, Moradabad is shown in table-1. It was found that in ground floor radon concentration varied from 12 Bq/m^3 to 20.66 Bq/m^3 with an average of 16.8 Bq/m^3 and thoron concentration from 10.5 Bq/m^3 to 18.5 Bq/m^3 as well as for first floor, radon and thoron concentration 15.0 to 23.0 Bq/m^3 and 13.0 to 20.5 Bq/m^3 respectively. The ventilation condition of the residential dwellings is one of the factors which decide the indoor ^{222}Rn and ^{220}Rn concentrations (Kumar et al., 2017).

The resulting concentration of short-lived radon daughters, expressed in term of an equilibrium-equivalent radon and thoron concentration (EEC), is related to the activity concentration (Ac) of radon and thoron by the relation

EEC = F. Ac

F= Equilibrium factor of radon or thoron and its value is radon or thoron (0.4) and (0.1) respectively calculated by (Kandari et al., 2016 ; UNSCEAR 2008).

AC = Activity Concentration in Bq/m3

$$EEC = C \times F \tag{1}$$

Here, EEC is the equilibrium equivalent concentration of radon and thoron (EERC and EETC, resp.) C is the concentration of radon or thoron. F is the equilibrium factor of radon or thoron and its value is radon (0.4) and thoron (0.1) respectively.

Table 1. Observed average Indoor radon and thoron concentrations at different places in Rohilkhand Region, Moradabad

Locations	No of Houses	Ground Floor		First Floor		Average concentration	
		^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn	^{222}Rn	^{220}Rn
Pakwada	2	17.5	14.5	19.0	16.5	18.25	15.5
Lodhi Pura	3	16.0	13.5	20.0	18.5	18.0	16
Budhi Vihar	2	17.25	15.5	18.0	16.5	17.6	16
Khushal Pur	2	14.50	12.5	16.0	14.00	15.25	13.25
Prem Nagar	3	18.20	15.0	19.0	13.0	18.75	14.0
Gulab bari	2	19.00	16.5	20.00	15.5	19.5	16.0
Sita puri	2	14.50	12.5	15.00	14.5	14.75	13.5
Ram Ganga Vihar	3	19.75	17.5	21.00	18.5	20.3	18.0
Jigar Colony	2	12.00	10.5	15.00	13.5	13.5	12.0
Chandan Nagar	2	20.25	18.5	22.00	19.5	21.8	19.0
Mandi Chok	3	20.66	17.0	23.00	20.5	21.8	18.75
Hydel Colony	3	13.00	11.5	17.00	15.6	15.0	13.55
Mansrover	2	17.00	14.5	20.00	18.2	18.5	16.35
Max		20.66	18.5	23.00	20.5	21.83	19.5
Min		12.00	10.5	15.00	13.00	13.5	11.7
Average		16.8	14.5	18.8	16.4	17.8	15.45

Table 2. Equilibrium-Equivalent ^{222}Rn and ^{220}Rn corresponding radiation dose

Locations	No of sample	Indoor Concentration (Bq/m^3)		Equilibrium-Equivalent ^{222}Rn and ^{220}Rn	
		Radon(C_R)	Thoron(C_T)	EERC	EETC
Pakwada	2	18.25	15.5	7.40	1.55
Lodhi Pura	3	18.0	16	7.20	1.60
Budhi Vihar	2	17.6	16	7.04	1.60
Khushal Pur	2	15.25	13.25	6.10	1.32
Prem Nagar	3	18.75	14.0	7.50	1.40
Gulab bari	2	19.5	16.0	7.80	1.60
Sita puri	2	14.75	13.5	5.90	1.35
Ram Ganga Vihar	3	20.3	18.0	8.12	1.80
Jigar Colony	2	13.5	12.0	5.41	1.20
Chandan Nagar	2	21.8	19.0	8.70	1.90
Mandi Chok	3	21.8	18.75	9.10	1.87
Hydel Colony	3	15.0	13.55	6.00	1.35
Mansrover	2	18.5	16.35	7.40	1.63
Max		21.83	19.5	9.10	1.95
Min		13.5	11.7	5.40	1.17
Average		17.8	15.45	6.60	1.54
Median		18	16.0	7.2	1.6
Geometric Mean		17.6	15.5	7.07	1.7

The inhaled effective dose due to exposure of radon progeny has been calculated by the relation given by UNSCEAR:

$$E_{Rn} = C_c \times F \times T \times C \times 10^{-6} \quad (2)$$

E_{Rn}: Inhaled Effective dose (mSv/y),
C_c: Geometric mean of ^{222}Rn and ^{220}Rn concentration in (Bq/m^3)
F: Equilibrium Factor of ^{222}Rn is (0.4) and for ^{220}Rn is 0.02
T: Time Daily work which is 8 hours (2920 h/y) is 7000h
C: Conversion coefficient of ^{222}Rn is (9) and For ^{220}Rn is(40) nSv (Bqh/m^3)-^{1} and 10^{-6} is nano Sv conversion coefficient to mSv/y

Calculation of annual effective doses of ^{222}Rn and ^{220}Rn

The annual effective dose due to exposure of radon progeny has been calculated by the relation given by UNSCEAR:

$$D_{ER}\,(mSv/y) = EERC\,(Bq/m^3) \times 8760h \times 0.8 \times 9\,nSv\,(Bq.h/m^3)^{-1} \times 10^{-6} \quad (3)$$

Similarly, the effective dose due to exposure of thoron progeny may be calculated by the relation:

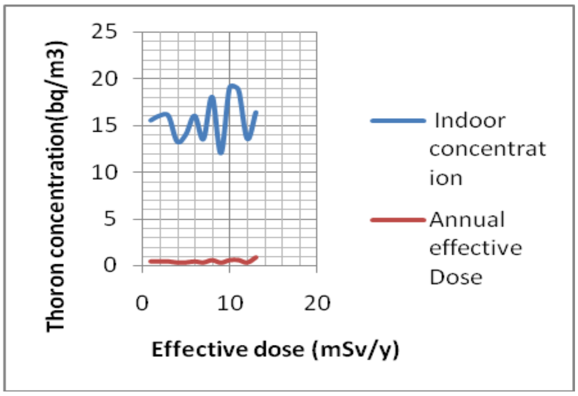
$$D_{ET}\,(mSv/y) = EETC\,(Bq/m^3) \times 8760h \times 0.8 \times 40\,nSv(Bq.h/m^3)^{-1} \times 10^{-6}$$

Where, EERC and EETC are the equilibrium equivalent concentrations of radon and thoron, respectively, in the houses of the study area. The numerical quantity 0.8 is the annual indoor occupancy factor, 9 and 40 are the dose conversion factors for radon and thoron progeny in nSv units, respectively. The multiplication factor 10^{-6} is used to convert the nSv units into mSv/y units.

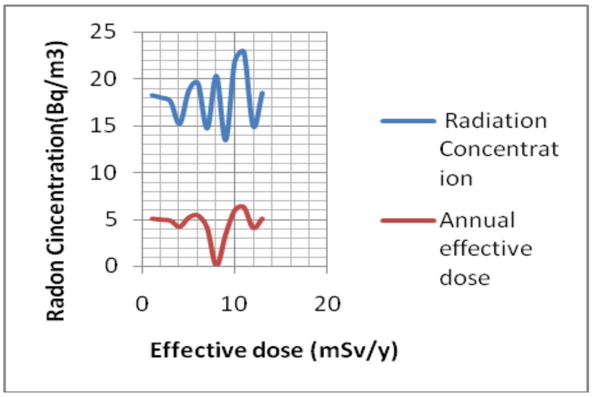
The annual effective dose due to indoor radon and thoron concentrations was estimated from the concentration of these isotopes in indoor environment (Table-3) (Graph-1, 2, 3) and using the occupancy factor of 7000 h/year (Pinel et al., 1995; UNSCEAR 2000) and dose conversion factor of 9 nSv/(Bq/m^{3}h) for radon and 40 nSv/(Bq/m^{3}h) for thoron .The effective doses due to radon and thoron progenies were estimated from corresponding WLM (working level month) values and conversion factors 3.9 and 3.4 mSv/WLM for radon and thoron progenies, respectivel**y.** (ICRP 1993; UNSCEAR 2008).

Table 3. Total indoor annual effective dose due to 222Rn and 220Rn corresponding radiation

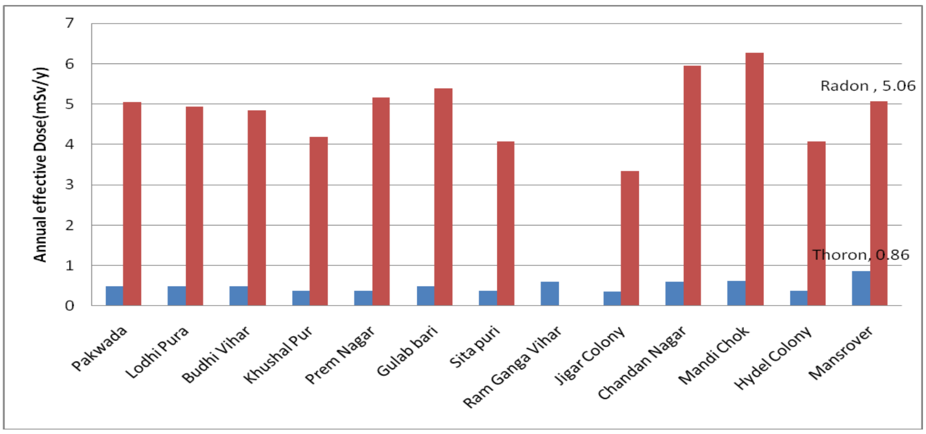
Locations	No of sample	Indoor Concentration (Bq/m^3)		Inhalation dose due to $^{222}Rn^{220}Rn$ (mSv/y)		Annual effective dose due to ^{222}Rn and ^{220}Rn(mSv/y)		Total annual effect dose (mSv/y)	
		Radon(C_R)	Thoron(C_T)	Radon	Thoron	Radon	Thoron	Radon	Thoron
Pakwada	2	18.25	15.5	0.45	0.08	4.6	0.4	5.05	0.48
Lodhi Pura	3	18.0	16	0.44	0.08	4.5	0.4	4.94	0.48
Budhi Vihar	2	17.6	16	0.44	0.08	4.4	0.4	4.84	0.48
Khushal Pur	2	15.25	13.25	0.38	0.07	3.8	0.3	4.18	0.37
Prem Nagar	3	18.75	14.0	0.47	0.08	4.7	0.3	5.17	0.38
Gulab bari	2	19.5	16.0	0.49	0.09	4.9	0.4	5.39	0.48
Sita puri	2	14.75	13.5	0.37	0.08	3.7	0.3	4.07	0.38
Ram Ganga Vihar	3	20.3	18.0	0.51	0.10	5.1	0.5	5.61`	0.60
Jigar Colony	2	13.5	12.0	0.34	0.06	3.4	0.3	3.34	0.36
Chandan Nagar	2	21.8	19.0	0.54	0.10	5.4	0.5	5.94	0.60
Mandi Chok	3	22.8	18.75	0.57	0.11	5.7	0.5	6.27	0.61
Hydel Colony	3	15.0	13.55	0.37	0.07	3.7	0.3	4.07	0.37
Mansrover	2	18.5	16.35	0.46	0.09	4.6	0.4	5.06	0.86
Max		21.83	19.5	0.57	0.11	5.7	0.5	6.27	0.37
Min		13.5	11.7	0.34	0.06	3.4	0.3	3.74	0.61
Average		17.8	15.45	0.45	0.08	4.5	0.7	4.95	0.78
Median		18.0	16.0	0.45	0.08	4.6	0.4	4.9	0.48
Geometric mean		17.6	15.5	0.40	0.08	4.4	0.37	4.7	0.42



Graph. 1. Effective dose due Thoron radiation



Graph. 2. Effective dose due Radon radiation



Graph. 3. Graphical variation of annual effective dose due to Radon & thoron radiation

CONCLUSION

In the present study, we measured the values of radon and thoron levels in the indoor environment of some dwellings of Rohilkhand region (Moradabad) Uttar Pradesh, India. Equilibrium-Equivalent concentration, Total Annual effective dose has also been calculated for the occupants of these dwellings. The conclusions of the present study are as follows:

- The overall average value of radon and thoron in the present study is found to be 17.8 Bq/m^3 and 15.4 Bq/m^3 respectively The concentration of radon and their progeny levels in the study area were observed below the recommended action level (200Bq/m^3) set by the various organizations (ICRP, 1993).
- The geometric mean value of equilibrium equivalent concentration is found 7.07 and 1.7 respectively. The value of EERC and EETC are used to calculate inhaled effective dose.
- The value of total annual effective does due to radon 3.7 to 6.27 mSv/y and thoron 0.3 to 0.61 mSv/y The total annual effective dose in the study area were observed below the action level 3-10 mSv/y as recommended by ICRP.

Therefore, it is concluded that the study area is quite safe from radiation protection point of view. As the variation of annual exposure and inhalation dose due to radon and thoron.

The ventilation conditions and floor materials of the dwellings play an important role in order to decide the values of indoor radon / thoron concentration and effective dose. Therefore, it is concluded that, the radon concentration values are found to be higher in dwellings with poor ventilation

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