ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11,S Iss 1, Oct 2022

To Study The Variation Of Indoor Radon, Thoron & Their Progeny Concentration And Dose Estimation Derived From Their Exposure In Dwellings Of Bareilly District Of Uttar Pradesh.

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ABSTRACT

The variation of indoor radon, thoron and their progeny concentration in the dwellings of Bareilly, Uttar Pradesh has been carried out using solid state nuclear track detector (SSNTD). The equilibrium factor for radon & thoron and annual doses received due to radon and thoron by the inhabitants in the dwellings under study area has also been calculated from observed results. Based on the results it is found that the radon concentration varies from 10.23 Bq/m^3 to 92.39 Bq/m^3 with an average of (44.07) Bq/m^3 while the thoron concentration in same dwellings varied from 10.45 Bq/m^3 to 41.25 Bq/m^3 with an average of 17.51 Bq/m^3. The radon progeny levels (EERC) is found to vary from 08.36 Bq/m^3 to 27.58 Bq/m^3 with an average of 13.81 Bq/m,^{3} while thoron progeny levels (EETC) varies from 0.21 Bq/m^3 to 2.23 Bq/m^3 with an average of 0.99 Bq/m^3. Equilibrium factor for radon and thoron have been found to vary from 0.12 to 0.89 with an average of 0.36 and 0.01 to 0.22 with an annual average of 0.06 respectively. The estimated value of total annual inhalation dose was found to vary from 0.67 mSv/y to 2.18 mSv/y with an average of 1.19 mSv/y. The observed values of radon concentration under study area is little higher than average national level of radon concentration 42 Bq/m3 (Mishra et al., 2009.) The observed value of thoron concentration in Bareilly is 0.44 times higher than average national level of thoron concentration 12.2 Bq/m3 (Mishra et al., 2009)

Keywords; Radon, Thoron, Progeny, Annual effective dose, SSNTD, radiation exposure.

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INTRODUCTION

Members of the general public can be exposed to elevated radon progeny levels mainly owing to radon entry from the ground into houses, by radon exhalation from building materials into the room air, and by the use of radon-containing water for cooking, consumption, or sanitary purposes. Radon and its short lived decay products (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po) present in dwellings are a radiation hazard, particularly if such sources are concentrated in enclosed areas like poorly ventilated houses and underground mines. There is a risk of lung cancer from the inhalation of radon due to the alpha radiation emitted by the short-lived radon decay products. To estimate the annual average equivalent dose, a number of indoor radon surveys have been carried out around the world (UNSCEAR, 1993). Inhalation exposure of the general population to ambient radon progeny constitutes the most significant health hazard of the natural radiation environment (Pohl et al., 1976). It is generally accepted by the scientific community that a considerable fraction of all naturally

ISSN PRINT 2319 1775 Online 2320 7876

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occurring lung tumors is caused by inhalation of the short-lived radon progeny (NCRP, 1984). This risk is exacerbated for certain identifiable subpopulations, such as tobacco smokers and uranium miners (Wagoner et al., 1965; Sevc et al., 1976; American Cancer Society, 1981; Whittemore and McMillan, 1983 ;). The assessment of radiological risk related to inhalation and ingestion of radon and radon progeny is based mainly on the integrated measurements of radon (ICRP, 1993; Ramola et al., 1997). Dose calculations indicate that the effective dose would be 20-50% higher for children than that for adults (Hofmann, 1982; US National Research Council, 1991). However, the sensitivity of the children for radon exposure is not known. According to the mine data the relative risk coefficient decreases with age and with the time since exposure. The miner data support the presence of an inverse dose-rate effect as well as a lower relative risk coefficient at low total dose (Lubin et al., 1995). Exposure of person to high concentration of radon and its short-lived progeny for a long period leads to pathological effects like respiratory functional change and the occurrence of lung cancer (Lubin and Boice, 1993; Ramola et al., 2005). In some countries, the radiation dose to man caused by inhaled radon daughters constitutes more than 50% of the total (UNSCEAR, 2000). Any inhaled gas, including radon, is slightly soluble in body tissues. Radon in the lung diffuses to blood and is transported to other organs, where the gas and the decay products that build up in the tissue deliver a radiation dose. Harley et al. (1958), in a study of inhaled radon, determined the solubility of radon in the body. Two persons were in a controlled, relatively high-radon atmosphere for about a day. Sequential exhaled-breath samples were used to infer retention times in the five major body-compartments-lung, blood, intracellular and extra cellular fluid, and adipose tissue. The data were used in the metabolic modeling of the dose to other organs from inhaled radon (Harley and Robbins, 1992). Radon, thoron and their short-lived decay products contribute to population the annual average effective dose equivalent of about 1 mSv per person. This amount is often higher in the uranium and thorium rich areas, especially near the mines and mille. Therefore it is necessary to monitor the environmental radioactivity around these objects and to assess the influence of radiation to the population.

Inhalation dose

The inhalation dose is directly related to the total potential alpha energy concentration (PAEC) of the daughter nuclides and is generally expressed in working level (WL) units. The concept of the working level (WL), a radon progeny concentration unit, developed as a measure of the potential occupational exposure of uranium miners. It has been widely used as a measure of environmental concentration of radon progeny in indoor air and has been extended to thoron progeny as well.

Experimental procedure

The measurement of indoor radon, thoron & their progeny has been carried out by using solid state nuclear track detector (SSNTD) and deposition based radon/thoron progeny sensor.

Measurement of indoor radon and thoron concentration.

The measurement of ^{222}Rn & ^{220}Rn concentration was carried out in residential houses of Bareilly using pin hole based ^{222}Rn /^{220}Rn discriminator dosimeter. The details and calibration of pin hole based ^{222}Rn /^{220}Rn discriminator dosimeter was described elsewhere (Sahoo et, al. 2013). Fig. 1 schematic diagram of pin hole dosimeter.

The solid state nuclear track detector (LR115 types II film) of size (2.5 × 2.5 cm^2) was fixed at opposite end of the entry face in each chamber. The LR 115 type II film in first chamber measured track produced by α emitted from radon and thoron, while second chamber

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Research paper UGC CARE Listed (Group -I) Journal Volume 11,S Iss 1, Oct 2022

measured tracks due to radon only. The dosimeters were deployed in the residential houses at the height of about 2 m from the floor and 20 cm away from any surface. After an exposure period of 90 days, the detector were retrieved from dosimeters and chemically etched with 10% of NaOH solution at 60^0c for 90 minutes without stirring (Ramola et al. 1996, Ramachandran, 1998). Tracks recorded in SSNTD films were counted using spark counter. This measurement was repeated on a time integrated four quarterly cycles to cover all the four seasons of a calendar year.

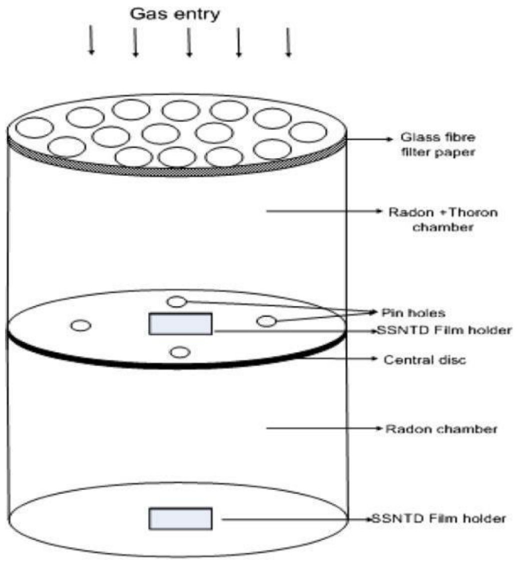

Fig. 1 schematic diagram of pin hole dosimeter.

Measurement of radon and thoron progeny concentration.

The concentrations of ^{222}Rn & ^{220}Rn progeny were measured by using deposition based direct radon and direct thoron progeny sensors (DRPS and DTPS). These are made of passive nuclear track detectors (SSNTD) mounted with the absorbers of appropriate thickness. For thoron progeny , the absorber is 50 µm aluminized Mylar and which selectively detects only 8.78 Mev α- particles emitted from ^{212}Po ; while for radon progeny , the absorber is a combination of aluminized Mylar and Cellulose nitrate of effective thickness 37 µm to detect mainly 7.67 Mev α- particles emitted from ^{214}Po. This thickness mainly ensures that lower energy alpha emissions (from the gases and other airborne alpha emitters) do not pass through the absorber **(Mishra et. al., 2009**). Since the system is intended for use in the deposition mode, it is necessary to avoid uncontrolled static charges from affecting the deposition rates and hence aluminized side of the Mylar was chosen to act as the deposition surface (**Mishra et. al., 2009)**.

The tracks recorded in the exposed LR 115 film is related to Equilibrium Equivalent Concentration (EEC) using sensitivity factor. The number of tracks per unit time (T) can be correlated to the Equilibrium Equivalent Progeny Concentration in air using the sensitivity factor (S) (Mishra and Mayya 2008).

Direct Radon Progeny Sensor

Absorber

Aluminized Mylar + Cellulose Nitrate (25µm+12µm=37µm) 214Po - 7.67 MeV (α- Particle)

Direct Thoron Progeny Sensor

Absorber

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Aluminized Mylar (50µm)
212Po- 8.78 MeV(α- Particle)

Fig.2. Direct Radon and Thoron progeny sensors.

Important formulas used in calculation of indoor radon and thoron & their progeny concentration.

For calculating radon and thoron concentration from the track density of pin hole dosimeter.

For radon concentration, $C_R(Bq/M^3) = T_1/\ (d\ .k_R)$

For thoron concentration, $C_T(Bq/M^3) = (T_{2}\text{-}d\ C_R\ k_R'\ )/(d\ .k_T)$

where, T_1 is the track density observed in radon chamber. k_R is the calibration factor of radon in radon chamber. For radon, k_R (0.019 ± 0.003 tr. cm^{-2} per Bq.d.m^{-3}), d is the number of days of exposure time. T_2 is the track density observed in "radon + thoron" chamber, k_R' (0.019 ±0.003 tr. cm^{-2} per Bq.d.m^{-3}) and k_T (0.016 ± 0.005 tr. cm^{-2} per Bq.d.m^{-3}) are the calibration factors of radon and thoron in "radon + thoron" chamber.

Equilibrium Equivalent Radon and Thoron Concentration were calculated as –

EEC (Bq/m^3) = T (Tracks. cm^{-2} .d^{-1})/S [Tracks. cm^{-2} .d^{-1}/EEC(Bq/m^3)]

Where S= 0.94 Tracks. Cm-2.d-1/EETC (Bq/m^3) for thoron progeny and

S = 0.09 Tracks. Cm-2.d-1/EERC (Bq/m^3) for radon progeny.

Estimation of total annual inhalation dose.

Annual dose received by the inhabitants in the dwellings under study in mSv/y was estimated using the relation

$$D = \{(0.17 + 9\ F_R)\ C_R + (0.11 + 40\ F_T)\ C_T\}\ x\ 8760x\ 0.8\ x\ 10^{-6}$$

where, F_R and F_T are the equilibrium factors for radon and its progeny and thoron and its progeny, respectively. C_R and C_T are the radon and thoron concentrations in Bq/m^3, respectively. The quantities 0.17 and 9 are dose conversion factors for radon and its progeny concentrations, respectively while the quantities 0.11 and 40 are the dose conversion factors for thoron and its progeny concentrations in mSv units, respectively UNSCEAR, 2000. The indoor occupancy factor was assumed 0.8 as standard for the study area (Mayya, Y. S et al 1998). The multiplication factor 10^{-6} is used to convert the mSv units into mSv units. Since

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the equilibrium factors vary with environmental factors, these factors have been estimated independently for individual dwellings separately. Note that with new radon dosimeter currently elaborated by the ICRP, the doses could be a factor 2 to 3 higher (Harrison J. D et al, 2012; Brudecki, K. et al, 2014).

Estimation of equilibrium factor

In previous studies, it has been a usual practice to estimate the radiation dose quantities due to exposure of radon, thoron and their progeny using worldwide assumed value (0.4) of equilibrium factor for radon and its progeny. However, the equilibrium factor depends largely on the environmental conditions such as hours and modes of ventilation, humidity, time, dwellings etc. (Porstendorfer et al 1984; Jilek, K,2010; Ramola, et al, 2003,2010; Nikezic, D,2011).

In disparity, thoron equilibrium factor varies remarkably even for the similar environment due to wide variation of thoron concentration arising from its short lived nature. The very short half-life of thoron results in non-uniformity of thoron concentration in the indoor environment. Hence it is not advisable to estimate radiation doses of thoron using the gas concentration and an equilibrium factor which depends on the sampling protocol, in addition to environmental factors as for radon. In the present study, direct measurements of the decay products concentrations and gas concentrations were carried out by using direct progeny sensors and pin-hole dosimeter techniques, respectively. The equilibrium factor for radon and its progeny and thoron and its progeny were then simply calculated for individual dwellings by using the following expressions:

$$\text{Equilibrium Factor for Radon} = \frac{\text{EERC}}{\text{Radon Concentration}}$$

$$\text{Equilibrium Factor for Radon} = \frac{\text{EETC}}{\text{Thoron Concentration}}$$

Where, the quantities radon concentration, thoron concentrations, EERC and EETC represent the arithmetic means over the measurement period (about 3 months). *(*Mishra R. et al 2014).

Results and discussion

The seasonal variation in indoor radon, thoron, their progenies and equilibrium factor in the in the residential houses of Bareilly are shown in table below.

	Summer Season				Rainy Season				Winter Season				Autumn Season			
	Min.	Max.	Mean	S D	Min.	Max.	Mean	S D	Min.	Max.	Mean	S D	Min.	Max.	Mean	S D
Radon	10.23	58.03	36.28	9.22	14.96	70.5	39.46	11.48	15.07	92.39	51.41	18.67	15.88	68.49	41.33	15.05
EERC	8.36	27.58	12.93	4.49	8.12	26.04	13.51	4.54	8.11	24.79	15.32	3.30	7.35	24.5	13.49	3.56
F for Radon	0.14	0.48	0.32	0.49	0.16	0.70	0.36	0.12	0.16	0.86	0.39	0.15	0.13	0.89	0.36	0.16
Thoron	10.45	35.02	14.67	6.44	8.06	35.2	16.23	6.15	10.87	41.25	18.63	4.67	5.26	35.01	17.33	6.43
EETC	0.21	1.95	0.96	0.32	0.38	1.70	1.08	0.25	0.13	2.02	0.96	0.43	0.52	2.23	0.97	0.34
F for Thoron	0.02	0.12	0.05	0.03	0.02	0.13	0.07	0.03	0.01	0.12	0.05	0.03	0.02	0.22	0.06	0.03
Dose	0.68	1.86	1.08	0.26	0.71	2.18	1.20	0.32	0.67	2.10	1.31	0.27	0.73	2.10	1.18	0.26

ISSN PRINT 2319 1775 Online 2320 7876

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The measured values of radon, thoron, their progenies, equilibrium factor and estimated dose for different seasons in Bareilly are shown in the Table 1. From the table it is observed thatthe values of radon and thoron concentrations have been found to vary from 10.23 Bq/m^3 to 92.39 Bq/m^3 with an annual average of 44.07 Bq/m^3 and 10.45 Bq/m^3 to 41.25 Bq/m^3 with an annual average of 17.51 Bq/m^3, respectively. The measured values of equilibrium equivalent radon concentration (EERC) and equilibrium equivalent thoron concentration (EETC) have been found to vary from 8.36 Bq/m^3 to 27.58 Bq/m^3 with an average of 13.81 Bq/m^3 and 0.21 Bq/m^3 to 2.23 Bq/m^3 with an average of 0.99 Bq/m^3, respectively. The values of equilibrium factor for radon and thoron have been found to vary from 0.12 to 0.89 with an annual average of 0.36 and 0.01 to 0.22 with an annual average of 0.06 respectively.

Conclusion.

The observed values of radon concentration under study area is little higher than average national level of radon concentration 42 Bq/m3 (Mishra et al., 2009.) The observed value of thoron concentration in Bareilly is 0.44 times higher than average national level of thoron concentration 12.2 Bq/m3 (Mishra et al., 2009). The equilibrium factor for radon and its progeny (0.36) has been found to be lower than its globally assumed value (0.4). The value of equilibrium factor for thoron and its progeny (0.06) has been found to also lower than the globally assumed value (0.1). It was found that the radon progeny and the equilibrium factor depend largely on the environmental conditions, which may results in the variation in dose calculation. The large variation in measured values of equilibrium factor suggests that while calculating the radiation dose due to the exposure of radon, thoron and their progeny, the equilibrium factors should be determined separately for individual dwelling. In this study it is desired that the values of equilibrium factors for radon and thoron are reproducible in thestudy area with recently developed pin-hole dosimeter and DTPS/DRPS techniques. The annual inhalation dose due to exposure of radon, thoron and their progeny have been found with in the safe limits as recommended by UNSCEAR, 2000. In general, the radiation doses have shown no significant health risk due to exposure of radon, thoron and progeny in the study area.

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