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Study of radon, thoron concentration and annual effective dose in some dwellings of Aligarh city Uttar Pradesh and Dwarka Delhi, India

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KEYWORDS

Indoor radon and thoron; Twin chamber dosimeter cup; annual effective dose; LR-115 type II plastic track detector; SSNTDs.

A B S T R A C T

In the present study Solid State Nuclear Track Detector (SSNTD) based twin chamber dosimeters were used for estimating radon (^{222}Rn) and thoron (^{220}Rn) gases and annual effective dose in some dwellings of Aligarh city Utter Pradesh and Dwarka Delhi, India. The dosimeters employ two LR-115 type II peliculable, cellulose nitrate detector films inside each of the two chambers fitted with filter and polymeric membrane for the discrimination of radon and thoron gases. Etched tracks in the exposed detectors were counted by spark counting system. In the dwellings of Aligarh city, radon concentrations was found to vary from 5.7 Bq m^{-3} to 19.2 Bq m^{-3} with an average value of 12.8 Bq m^{-3}, Thoron concentrations was found to vary from 3.7 Bq m^{-3} to 17.6 Bq m^{-3} with an average value of 9.4 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 0.16 to 0.55 mSv. However, the annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.44 mSv. In the Flats of Dwarka, Delhi radon concentrations was found to vary from 4.3 Bq m^{-3} to 12.4 Bq m^{-3} with an average value of 23.9 Bq m^{-3}, Thoron concentrations was found to vary from 3.8 Bq m^{-3} to 12.3 Bq m^{-3} with an average value of 22.4 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 0.12 to 0.35 mSv. The annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.31 mSv.

Introduction

Radon, thoron and their progeny exposure due to their detrimental effects on the health of the inhabitants because, precisely, out of 98% of average radiation dose received by man from natural sources, about 52% is due to breathing of radon, thoron and their progeny present in the dwellings (UNSCEAR, 1988). UNSCEAR (2000), reports estimate that the contribution of thoron and its decay products to the annual effective dose from radon is about 8%. The presence of thoron might cause problems for radon measurements, since radon and thoron are isotopes of same element, their separation can only be based on the large difference of decay rates of the two isotopes (Cross and Tommasino, 1970). A relationship between lung cancer and inhalation of radon and its decay products has been demonstrated so, monitoring of radon and thoron in dwellings is important from the point of view of radiation hygienic.

Exposure to Radon (^{222}Rn) and its progeny in indoor atmosphere can result into significant inhalation risk to population particularly to those living in homes with much higher levels of radon. Natural radiation which originates from the Earth crust, cosmic radiations etc. are the major contributors to the total background exposures to human population. All radiations give a world average value of 2.4 mSv for the annual effective dose equivalent from natural back ground radiation of which 1.4 mSv comes from the radon, thoron and their daughter products (Nambi et al., 1986, UNSCEAR, 1993).

Radon is estimated to cause thousands of deaths worldwide each year. As the radon progeny contributes a major part of natural radiation dose to general population, attention has been given to the large scale and long-term measurement of radon and its progeny. It is assumed that the inhalation dose to the human beings from thoron and its progeny is negligible although recent studies in many countries have revealed that this may not be entirely correct (Steinhauser et al., 1994). Thoron and its progeny contribute little for the radiation dose in normal back ground region due to its small half life.

Solid State Nuclear Track Detectors (SSNTD's) based twin chamber dosimeters were used for estimating radon (^{222}Rn) and thoron (^{220}Rn) gases and annual effective dose in some dwellings Aligarh city near Narora Atomic Power Station (NAPS). Narora is located on the banks of Ganges river in the district Bulandshahar of U.P. (India). Nuclear power station has two reactors rated at 220MWe. The plant is located in seismic zone and is about 150 km away from New Delhi, capital of India and Dwarka is an up-market and one of the most sought-after residential areas/sub city, located in the South West Delhi district of the National Capital Territory of Delhi, India. It is named after the legendary Dwaraka Kingdom. It is a short distance away from Gurgaon which is a major hub for large corporations in the country and about 10 km away from Indira Gandhi International Airport. Some parts of modern day Dwarka historically came under the colony of *Pappan Kalan*, which are now being developed under the 'Urban Expansion Projects' of the Delhi Development Authority.

The contribution of thoron and its decay products to the annual effective dose from radon is 8% UNSCEAR, (2000). The presence of thoron might cause problems for radon measurements, since radon and thoron are isotopes of same element.

Experimental Methods

The radon - thoron dosimeter employed for the measurements is made up of a twin cup cylindrical system, developed at the Bhabha Atomic Research Centre (BARC) and is reported elsewhere (Mayya et al., 1998; Eappen and Mayya, 2004). Figure 1 shows the schematic representation of the twin cup dosimeter. Each chamber has a length of 4.1cm and a radius of 3.1cm. The SSNTD-

1(LR-115 type II) placed in compartment M, measures radon alone which diffuses into it from the ambient air through a semi-permeable membrane (Latex) of 25μm thickness having diffusion coefficient in the range of 10^{-8}-10^{-7} cm^2s^{-1} (Wafaa Arafa, 2004). It allows the build up of about 90% of the radon gas in the compartment and suppresses thoron gas concentration by more than 99% (The mean time for radon to reach the steady state concentration inside the cup is about 4.5 h). On the other hand, the glass fiber filter paper of 0.56mm thickness in the compartment F allows both radon and thoron gases to diffuse in and hence the tracks on SSNTD-2 placed in this compartment F, are related to the concentrations of both the gases.

Third piece of detector (SSNTD-3) film, exposed in bare mode (placed on the outer surface of the dosimeter) registers alpha tracks attributed to both the gases and their alpha emitting progeny, namely ^{218}Po, ^{214}Po and ^{212}Po. By subtracting the result of SSNTD-1 from SSNTD-2, thoron concentration has been determined. The choice of the detector LR-115 is made in view of the fact that the detector does not develop tracks originating from the progeny alphas deposited on them (Eappen and Mayya, 2004) and, therefore are ideally suited for radon and thoron concentration measurements. These dosimeters with membrane and the LR-115film have been suspended from the mid-point of the ceiling of the houses at a height of about 2.5m from the ground level. At the end of 100 days the dosimeters were retrieved to lab. The exposed detectors have been etched in 10% NaOH at 60^{o}C for a period of 1hour in a constant temperature bath. After etching, the detectors were pealed off from the plastic base and counted for tracks using a spark counter. From the counts the track density of the films has been calculated. The calibration factors have been obtained by using the setup described by Eappen and Mayya (2004). From track density, concentration of radon (C_R) and thoron (C_T) concentration were calculated using the sensitivity factor determined from the controlled experiments (Mayya et al., 1998; Sannapa et al., 2003; Jyoti et al: 2014):

$$C_R(Bqm^{-3}) = \frac{T_m}{d \times S_m} \quad \text{--------} \quad (1)$$

$$C_T(Bqm^{-3}) = \frac{(T_f - d \times C_R \times S_{rf})}{d \times S_{tf}} \quad \text{--------}(2)$$

Where, C_R -Radon concentration; C_T -Thoron concentration; T_{m}-= Track density in membrane compartment; T_f - track density in filter compartment and d - Exposure time. Sensitivity factor for membrane compartment (S_m) was taken 0.019 ± 0.003 Trc m^{-2} d^{-1}/Bq m^3 and sensitivity factor (S_{rf}) and (S_{tf}) for radon and thoron as 0.020 ± 0.004 and 0.016 ± 0.005 Trc m^{-2} d^{-1}/Bq m^{-3} respectively.

The annual effective dose due to exposure to radon and progeny in the houses of study area were calculated by the relation (UNSCEAR, 2000) :

Annual effective dose = C_R (Bq m^{-3}) × 0.46 × 7000h × 9nSv (Bqh m^{-3})$^{-1}$ -------------(3)

The annual effective dose due to exposure to thoron and progeny in the houses of study area were calculated by the relation (UNSCEAR, 2000) :

Annual effective dose = C_T (Bq m^{-3}) × 0.09 × 7000h × 40nSv (Bqh m^{-3})$^{-1}$ ------------(4)

Results and Discussion

Table-1 shows Levels of radon, thoron and gamma dose rate in the some houses of Aligarh city Utter Pradesh, India and Table-

2 shows Levels of radon, thoron and gamma dose rate in the some Flats of Dwarka, Delhi state of India. In the dwellings of Aligarh city, radon concentrations was found to vary from 5.7 Bq m^{-3} to 19.2 Bq m^{-3} with an average value of 12.8 Bq m^{-3}, Thoron concentrations was found to vary from 3.7 Bq m^{-3} to 17.6 Bq m^{-3} with an average value of 9.4 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 0.16 to 0.55 mSv with an average value of 0.37 mSv.

Table.1 Levels of radon, thoron and gamma dose rate in the some houses of Aligarh city Utter Pradesh, India

Location	**Indoor concentration (Bq m^{-3})**		**Annual effective dose (mSv)**	
	Radon (CR)	**Thoron (CT)**	**Radon**	Thoron
House no.-1	15.7	9.4	0.45	0.23
House no.-2	13.1	10.6	0.37	0.26
House no.-3	14	8.8	0.40	0.22
House no.-4	9.3	7.7	0.26	0.19
House no.-5	12.5	6.5	0.36	0.16
House no.-6	15.2	5.9	0.44	0.14
House no.-7	7.3	3.7	0.21	0.09
House no.-8	18.1	9.9	0.52	0.24
House no.-9	10.8	8.6	0.31	0.21
House no.-10	14.6	12.6	0.42	0.31
House no.-11	5.9	7.8	0.17	0.19
House no.-12	9.3	8.4	0.26	0.21
House no.-13	9.9	7.3	0.28	0.18
House no.-14	16.7	8.2	0.48	0.20
House no.-15	18.1	17.6	0.52	0.44
House no.-16	5.7	7.4	0.16	0.18
House no.-17	12.8	10.6	0.37	0.26
House no.-18	16.3	13.5	0.47	0.34
House no.-19	19.2	14.7	0.55	0.37
Min. Value	5.7	3.7	0.16	0.09
Max. Value	19.2	17.6	0.55	0.44
Average Value	12.8	9.4	0.37	0.23

Table.2 Levels of radon, thoron and gamma dose rate in the some Flats of Dwarka, Delhi state of India

Location	Indoor concentration (Bq m^{-3})		Annual effective dose (mSv)	
	Radon (CR)	Thoron (CT)	Radon	Thoron
Flat-1	23.6	9.2	0.68	0.23
Flat-2	13.1	9.2	0.37	0.23
Flat-3	23.9	11	0.69	0.27
Flat-4	13.4	10.2	0.38	0.25
Flat-5	10.2	13.5	0.29	0.34
Flat-6	7.6	12.7	0.22	0.32
Flat-7	4.6	3.8	0.13	0.09
Flat-8	11.1	14.5	0.32	0.36
Flat-9	10.8	11.4	0.31	0.28
Flat-10	12.2	17.2	0.35	0.43
Flat-11	10.5	11.1	0.30	0.27
Flat-12	8.1	9.9	0.23	0.24
Flat-13	11.9	14.8	0.34	0.37
Flat-14	4.9	5.5	0.14	0.13
Flat-15	22.8	18.7	0.66	0.47
Flat-16	6.4	7.9	0.18	0.19
Flat-17	11.1	13.5	0.32	0.34
Flat-18	16	19.1	0.46	0.48
Flat-19	18.1	22.4	0.52	0.56
Flat-20	15.4	15	0.44	0.37
Flat-21	9.3	12.6	0.26	0.31
Flat-22	4.3	7.0	0.12	0.17
Flat-23	12.8	10.3	0.37	0.25
Flat-24	5.2	8.0	0.15	0.20
Flat-25	7.3	9.6	0.21	0.24
Flat-26	5.5	8.3	0.15	0.20
Flat-27	9.6	11.5	0.27	0.28
Flat-28	19.5	16.4	0.56	0.41
Flat-30	21	16	0.60	0.40
Flat-31	22.2	19	0.64	0.47
Min. Value Max. Value Average Value	4.3 12.4 23.9	3.8 12.3 22.4	0.12 0.35 0.69	0.09 0.31 0.56

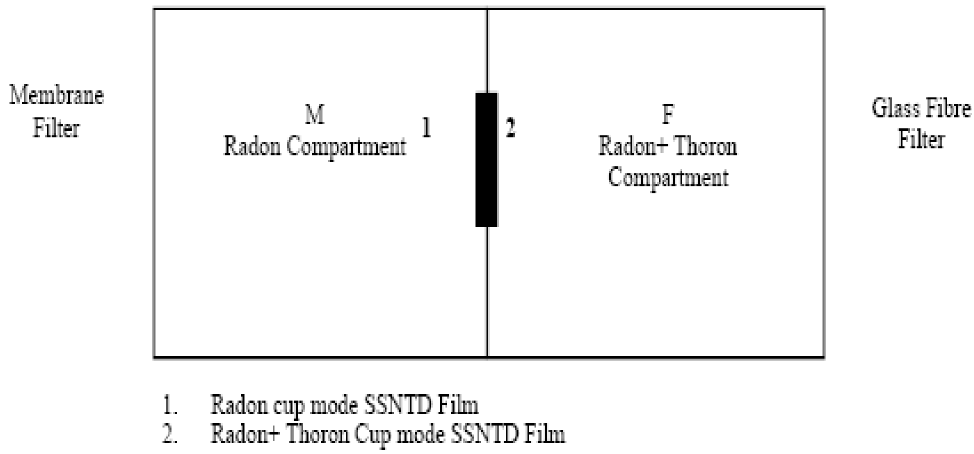

Fig.1 Schematic diagram of radon- thoron twin chamber dosimeter cup

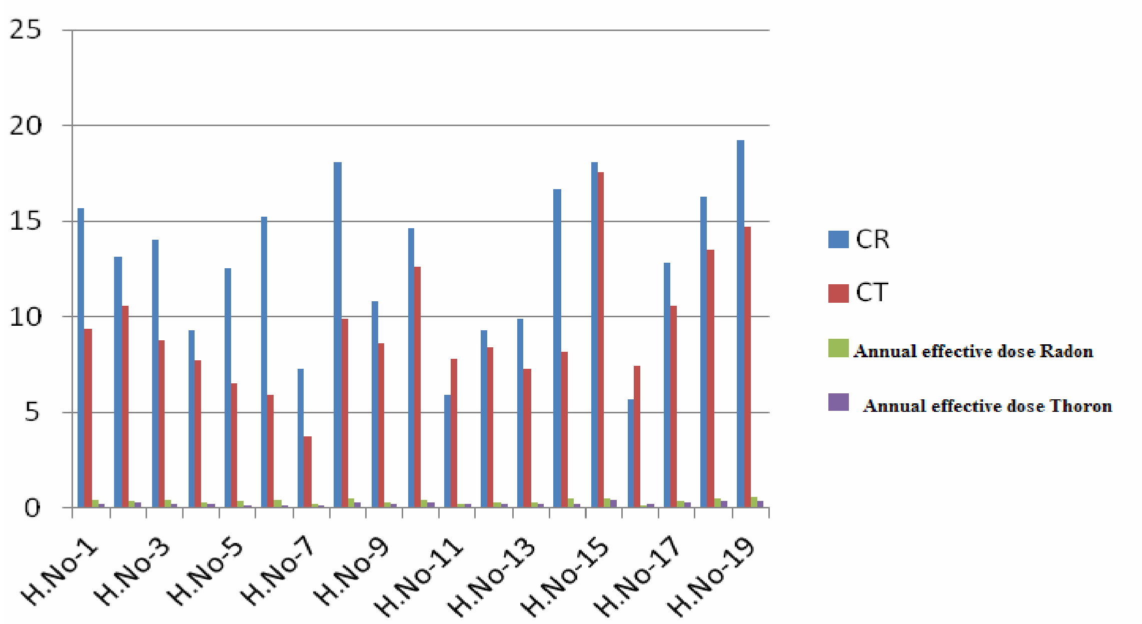

Fig.2 Variation of indoor radontThoron concentrations and annual effective dose in the some houses of Aligarh city Utter Pradesh, India

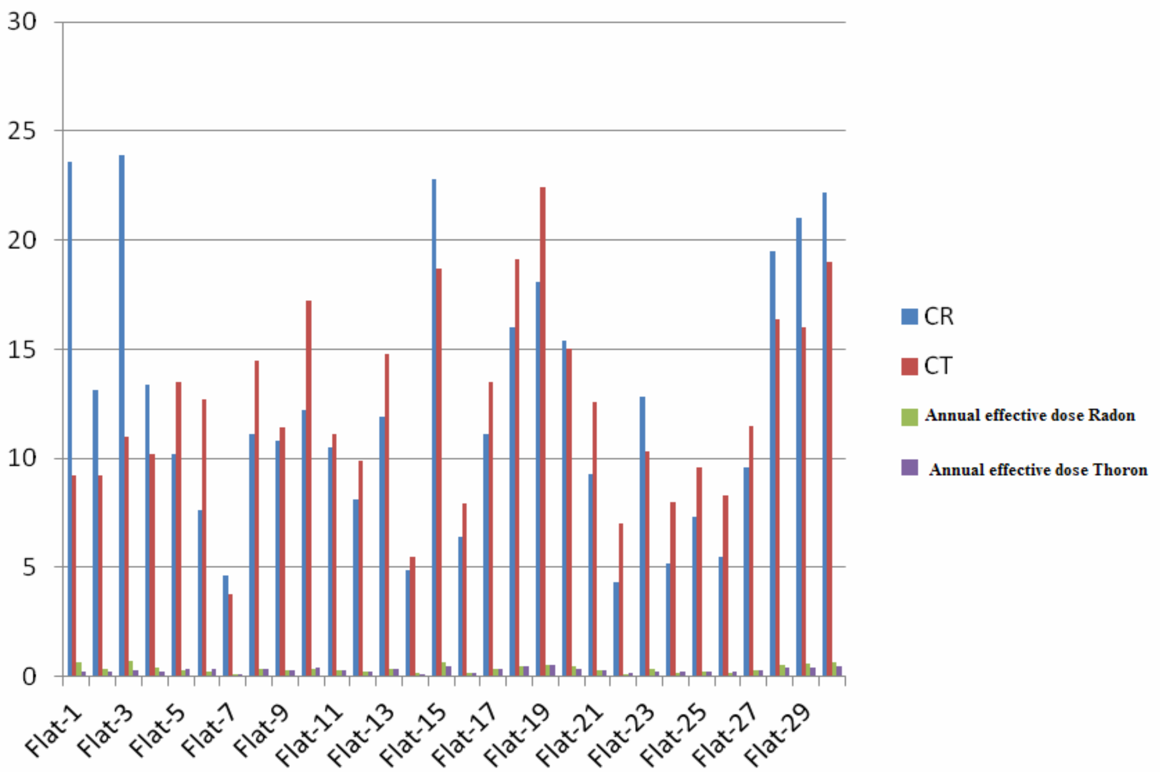

Fig.3 Variation of indoor radon,thoron concentrations and annual effective dose in the some Flats of Dwarka, Delhi state of India

However, the annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.44 mSv with an average value of 0.23 mSv. In the Flats of Dwarka, Delhi radon concentrations was found to vary from 4.3 Bq m^{-3} to 12.4 Bq m^{-3} with an average value of 23.9 Bq m^{-3}, Thoron concentrations was found to vary from 3.8 Bq m^{-3} to 12.3 Bq m^{-3} with an average value of 22.4 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 0.12 to 0.35 mSv with an average value of 0.69 mSv. The annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.31 mSv with an average value of 0.56 mSv. Fig.-2 and Fig. - 3 show the variation of Indoor Radon, Thoron Concentrations and annual effective dose in the some houses of Aligarh city Utter Pradesh, India and Flats of Dwarka, Delhi state of India

Radon daughter dose conversion factor for the population is given as 3.9 mSv per WLM whereas the effective dose equivalent for thoron is 3.4 mSv per WLM (ICRP, 1981). House wise analyses of radon and thoron and their daughter concentrations (Bq m^{-3}) show a wide variation. This wide variation in the concentration of both radon and thoron and their daughters may be attributed to the variation in primordial radioactivity in the region and to source extent ventilation condition. The variation in the consequent inhalation dose is the result of this variation together with other factors like ventilation, construction material and the type of the construction etc. The paper presented the preliminary results and further large scale measurements are in progress to determine the conclusive results. WHO (2009) recently recommended the levels of radon in the residental buildings as 100 Bq m^{-3}.

The annual effective dose, radon and thoron concentrations are within the permissible limits.

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