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• *Short report*

Measurements of indoor radon, thoron and their progeny in Farrukhabad city of Uttar Pradesh, India

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Background: More than 50% of the total dose received by human beings from all sources of radiation (both from natural and manmade) comes from radon and its progeny which is responsible for lung cancer in many cases. *Materials and Methods:* In the present study, the measurements have been carried out by using twin chamber dosimeter cups with LR-115 type-II detectors. The value of track density of detectors gives the concentration of radon, thoron and their progeny in different modes. *Results:* The average value of radon and thoron concentration was found 59 and 28 Bq/m^3, respectively. The inhalation dose was found to vary from 1.6 to 2.9 mSv/y. The average value of PAEC for radon and thoron was found 6.4 mWL and 0.75 mWL, respectively. Total annual exposure and annual effective dose varies from 0.23 to 0.39 WLM and 0.87 to 1.51 mSv/y respectively. The values of life time fatality risk was found to vary from 0.68 x 10^{-4} to 1.18 x 10^{-4}. *Conclusion:* These measurements show that the radon/thoron concentrations and annual effective dose received by the population of the area are well below the action level recommended by the International Commission on Radiological Protection (ICRP). **Iran. J. Radiat. Res., 2012; 10(3-4): 193-196**

Keywords: *Radioactivity, twin chamber dosimeter, track density, inhalation dose.*

INTRODUCTION

Radon and its daughters are the most important radio-nuclides present in the ambient air as well as in the indoor environment.

The radiation dose received by human beings due to the inhalation of radon, thoron and their progeny present in the indoor environment contribute about half of the average radiation dose from all natural sources of radiation. When radon inhaled, α-particles emitted by its short lived decay products can damage the cellular DNA mainly. Cellular mutagenesis studies, experimental research in animals, and occupational epidemiologic studies have established radon as a human lung carcinogen [1, 2].

As peoples spent a long occupancy time indoors so monitoring of indoor radon level is of utmost important to assess the health risks to the general population. The concentrations of indoor radon and its progeny vary from place to place because of its dependence on soils, building materials, wind speed and ventilation conditions [3, 4], so it is necessary to carried out a wide range survey of radon in the dwellings. In the last two decades various systematic indoor radon surveys have been carried out all over the world [5-9].

There are only limited studies related to the measurements of thoron in the environment in comparison with radon and its progeny, because it is assumed that the effective dose from thoron and its progeny is about 10% of that of radon and its progeny to the general public [10]. This paper reports the dosimetry of radon, thoron and their progeny in the dwellings of Farrukhabad city of Uttar Pradesh, India.

MATERIALS AND METHODS

Dosimeter cups

For the measurements of radon, thoron

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and their progeny, plastic twin chamber dosimeters with LR-115 type-II detectors (SSNTDs) have been used. It consists of twin chambers each having a length of 4.5 cm and a diameter of 3.1 cm. The SSNTDs used in this study was 12 μm thick, LR-115 type II α-particle sensitive layer of red dyed dielectric materials such as cellulose nitrate and polycarbonate. The SSNTD of size 2 cm x 1.5 cm is placed inside the both chambers (i.e. membrane and filter mode) of dosimeter cups. Another SSNTD of same size fitted in the space provided outside the dosimeter cup known as bare mode. These dosimeter cups were mounted in the houses at a height of about 2.5 m from the ground for exposure of about 90 days. At the end of this period of exposure, these cups were taken out and chemically etched in 2.5 N NaOH solution at a constant temperature of 60^0 C for about 90 minutes in order to reveal the tracks of alpha particles. After etching, the SSNTDs were properly washed in distilled water and dried. The tracks on SSNTDs were counted using an optical microscope of magnification 100X and the track density were determined which was used to calculate the concentration of radon, thoron and their progeny.

Radon-Thoron measurement

With the help of track density the concentration of radon and thoron were calculated by using the following relations [11, 12].

$$C_R(Bq.m^{-3}) = \rho_m / K_m.d \qquad (1)$$

$$C_T(Bq.m^{-3}) = \left(\rho_f - d.C_R \times K_{rf}\right)/K_{tf}.d \qquad (2)$$

Where C_R and C_T are the concentration of radon and thoron (in Bq/m^3) respectively, d is the time of exposure (in days), ρ_m and ρ_f are the track densities (in $tracks/cm^2$) of radon, and radon & thoron in membrane and filter mode, respectively. K_m is the calibration (or sensitivity) factors in membrane mode while K_{rf} and K_{tf} are the calibration factors for radon and thoron in filter mode. The numerical values of these factors are given as follows:

$K_m = (0.019 \pm 0.003\ tracks.cm^{-2}d^{-1}/Bq.m^{-3})$

$K_{rf} = (0.020 \pm 0.004\ tracks.cm^{-2}d^{-1}/Bq.m^{-3})$

$K_{tf} = (0.016 \pm 0.005\ tracks.cm^{-2}d^{-1}/Bq.m^{-3})$

The inhalation dose (in $mSv.y^{-1}$) was calculated by using the following expression [10].

$$D = \{(0.17 + 9F_R)C_R + (0.11 + 32F_T)C_T\} \times 0.007 \qquad (3)$$

Where F_R and F_T are known as the equilibrium factors for radon and thoron, and having the value of 0.4 and 0.1, respectively [13].

Radon-thoron daughter's measurement

The concentration of radon and thoron progeny in terms of Potential Alpha Energy Concentration (PAEC) (in mWL) was calculated by using the given formula [14]. For radon

$$C_R(Bq/m^3) = PAEC(mWL) \times 3.7 / F_R$$

or

$$PAEC(mWL) = (C_R \times F_R)/3.7 \qquad (4)$$

Similarly for thoron

$$PAEC(mWL) = (C_T \times F_T)/3.7 \qquad (5)$$

Generic relations have been used to calculate the annual exposure due to radon and its daughters [15] while the life time fatality [16] risk was calculated by using a factor of 3×10^{-4} WLM^{-1}.

The annual effective dose (mSv/y) was obtained by the conversion of PAEC, using a conversion factor of 3.9 mSv/WLM for radon and 3.4 mSv/WLM for thoron daughters.

RESULTS AND DISCUSSION

Table 1 shows the concentration of radon, thoron and inhalation dose present in the dwellings at different places of Farrukhabad city of Utter Pradesh, India. The concentration of radon and thoron varies from 45 to 79 Bq/m^3 and 10 to 49 Bq/m^3 with an average value of 59 Bq/m^3 and 28 Bq/m^3, respectively. The inhalation dose due to radon, thoron and their progeny was found to vary from 1.6 to 2.9 mSv/y with an average value of 2.2 mSv/y. Table 2 shows the radon, thoron daughters (PAEC) concentration, annual exposure due to radon and thoron, life time fatality risk and annual effective dose. The values of radon daughter's concentration (PAEC) vary from 4.8 to 8.6 mWL with an average value of 6.4 mWL while thoron daughter's concentration (PAEC) varies from 0.28 to 1.33 mWL with an average value of 0.75 mWL, respectively. The annual exposure from radon and thoron daughters collectively was vary from 0.23 to 0.39 WLM and the values of life time fatality risk was found to vary from 0.68×10^{-4} to 1.18×10^{-4}. However the values of annual effective dose found to vary from 0.87 to 1.51 mSv/y with an average value of 1.13 mSv/y respectively. Almost all the values shown in table 1 and table 2 are within permissible limit recommended by ICRP (14). The variation in the values of radon, thoron and their progenies may be due to the difference in the type of construction of the dwellings. The lower values of different parameters shown in table 1 and table 2 (i.e. from samples No. 1-5) corresponding to the dwellings having well concrete flooring, cement plastered, painted wall, large volume and good ventilation conditions. However, the dwellings have kutcha flooring, without plastered and painted wall, small volume and poor ventilation condition corresponding to the higher values (i.e. from S. No. 6-10). In these types of dwellings, the radon present in the soil directly comes into the contact with the indoor air resulting increase radiation level. All the values of radiation dose are lower than the worldwide average background radiation dose (10) of 2.4 mSv/y. On comparing with the similar measurements performed by Kant *et al.* (in winter season) (16) we found that our experimental values are slightly greater than their values. This may be due to the soil beneath the structure, use of construction materials having more exhalation rate and the ventilation conditions of the dwellings.

CONCLUSION

The measurements show that the values of the radon/thoron concentrations and annual effective dose (in winter) to the population of the area are below the action level; hence we can safely conclude that radon exposure is not a significant health hazard for the human beings of study area.

Table 1. Values of radon, thoron concentration and inhalation dose.

Sample No.	Corrected track density (ρ_m) (Tracks/cm^2)	Corrected track density (ρ_f) (Tracks/cm^2)	Radon conc. (C_R) (Bq/m^3)	Thoron conc. (C_T) (Bq/m^3)	Inhalation dose (D) (mSv/y)
1	80	120	45	24	1.7
2	80	130	45	31	1.9
3	90	110	51	10	1.6
4	90	150	51	37	2.2
5	100	140	57	23	2.0
6	110	160	62	24	2.2
7	110	150	62	23	2.2
8	120	200	68	50	2.9
9	130	170	74	22	2.4
10	140	240	79	35	2.9
Average			59	28	2.2
Standard Deviation			12	11	0.4

Table 2. Values of radon, thoron daughters (PAEC) concentration, annual exposure due to radon and thoron, life time fatality risk and annual effective dose.

Sample No	Radon daughters conc. (C_R) (mWL)	Thoron daughters conc. (C_T) (mWL)	Annual exposure (Rn) (WLM)	Annual exposure (Tn) (WLM)	Total Annual Exposure (Rn+Tn) (WLM)	Life time fatality risk factor ($x10^{-4}$)	Annual effective dose (mSv/y)
1	4.9	0.65	0.20	0.03	0.23	0.68	0.87
2	4.9	0.83	0.21	0.03	0.23	0.70	0.90
3	5.5	0.28	0.23	0.01	0.24	0.71	0.92
4	5.5	1.00	0.23	0.04	0.27	0.80	1.02
5	6.1	0.63	0.25	0.03	0.28	0.83	1.07
6	6.7	0.64	0.28	0.03	0.30	0.91	1.17
7	6.7	0.62	0.28	0.02	0.30	0.91	1.16
8	7.3	1.33	0.30	0.05	0.36	1.07	1.36
9	7.9	0.60	0.33	0.02	0.35	1.06	1.36
10	8.6	0.95	0.35	0.04	0.39	1.18	1.51
Av	6.4	0.75			0.29	0.88	1.13
SD	1.3	0.29			0.06	0.17	0.22

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