EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 Volume 2 Number 8 (August-2014) pp. 112-117

www.ijcrar.com

Measurement of indoor radon, thoron and annual effective doses in the some dwellings of Jaipur city, Rajasthan, India

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KEYWORDS

Radon,
Thoron,
Progeny,
Dwellings,
SSNTDs,
Annual effective dose

A B S T R A C T

Inhalation of radon and its daughter products can cause a significant health hazard when they are present in enhanced levels. 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. Gamma radiation emitted from ^{40}K and decay products in the ^{238}U and ^{232}Th decay series present in the ground and in building materials and starts accumulate in poor ventilated dwellings so, concentration of radon and its progeny are usually higher in indoor air than in outdoor air. The measurements of time integrated concentration of indoor radon and its daughters are important since indoor radon and its progeny is responsible for more than half of the total yearly radiation dose to human beings.The environmental monitoring of (^{222}Rn) and thoron (^{220}Rn) produced by the decay of naturally occurring uranium and thorium radioisotopes has been carried out in the dwellings of Jaipur city, Rajasthan. In this study Solid State Nuclear Track Detectors (SSNTD's) based twin chamber dosimeters were used for estimating radon (^{222}Rn), Thoron (^{220}Rn) gases and Inhalation dose. Radon concentrations was found to vary from 35.1 ± 4.5 Bq m^{-3} to 84.8 ± 7.0 Bq m^{-3} with an average value of 59.0 ± 5.9 Bq m^{-3}, Thoron concentrations was found to vary from 3.5 ± 0.3 Bq m^{-3} to 24.3 ± 2.2 Bq m^{-3} with an average value of 13.7 ± 1.3 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 1.02 to 2.46 mSv. However, the annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.61 mSv

Introduction

Exposure to Radon (^{222}Rn) and its progeny in indoor atmosphere can result 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 gives 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).

^{222}Rn is an inert radioactive gas with a half-life of 3.8 days and belongs to the radioactive uranium series.In recent years, ^{222}Rn has been used as tracer for the origin and trajectory of air masses (Larson and Bressan, 1980). Thoron, ^{220}Rn, is a natural decay product of thorium series. It has a half-life of 55.6 seconds and also emits alpha rays. Radon is a radiological poison and a carcinogen. Some of the daughter products from radioactive decay of radon (such as polonium) are also toxic. Since radon is a gas, its decay products form a very fine dust that is both toxic and radioactive. This can potentially stick in the lungs after inhalation and do far more damage than the radon itself (Darby, et al., 2001). Although these elements occur in virtually all types of rocks and soils, their concentrations vary with specific sites and geological materials. As an inert gas, radon can move freely through the soil from its source; the distances are determined by factors such as rate of diffusion, effective permeability of the soil and by its own half-life. The inhalation of short-lived daughter products of naturally occurring radon is a major contributor to the total radiation dose to exposed subjects. Radon progenies might be inhaled and deposited more or less deeply onto the bronchio-pulmonary tree, depending upon the granulometry of the particles on which they become attached. Under specific conditions, such as those prevailing in the uranium mining environment, lung dose due to radon progenies may be sufficiently high to cause an increase in the occurrence of lung cancer. Measurements of indoor radon are of importance because the radiation dose to human population due to inhalation of radon and its daughters contributes more than 50% of the total dose from natural sources (UNSCEAR, 1993).

The important factors that have got influence up on the indoor radon / thoron concentration are (1) Properties of the building construction materials and the ground. Here the radon exhalation rate from the building construction materials or the ground is dependent on the uranium/thorium content, density and the porosity of the material (2) Indoor radon / thoron concentrations are also influenced by the ventilation rate and metrological parameter.

Experimental Methods

Concentration of radon–thoron and annual effective dose rates in these dwellings were measured using the twin chamber Solid State Nuclear Track Detector (SSNTD) based dosimeters using12μm thick, LR-115 type II pelicullable, cellulose nitrate based SSNTDs manufactured by Kodak Pathe, France. The dosimeter has been developed at Bhabha Atomic Research Centre (BARC) and is shown figure 1. Each cylindrical chamber has a length of 4.1 cm and a radius of 3.1 cm. One piece of the detector film (SSNTD) of size 2cm × 2 cm. placed in compartment **M** measures radon only which diffuses into it from the ambient air through a semi-permeable membrane of 25 μm thickness having diffusion coefficient in the range of 10^{-8} to 10^{-7} cm^{-2} s^{-1} (Eappen and Mayya, 2004). It allows the build up of about 90% of 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 hour. Glass fiber filter paper of thickness of 0.56 mm in the compartment **F** allows both radon and thoron gases to diffuse in and hence the tracks on second piece of the detector film placed in this chamber are related to the concentrations of both the gases. Third piece of the detector 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, ^{216}Po, and ^{212}Po .LR-115 detectors do not develop tracks originating from the progeny alphas, deposited on them (Eappen et at., 1998; Nikolaev and IIlic 1999; Durrani.1997) and therefore, are ideally suited for radioactive gas concentration study. All the detectors were exposed for 100 days. After exposure the films were etched in 2.5 NaOH solution at 60^0C for 90 min in a constant temperature water bath. The etching processes removes a bulk thickness of 4μm leaving a residual detector for thickness of 8μm. The detectors are pre-sparked using spark counter (Cross and Tommasino, 1970) at a voltage of 900 V to fully develop the partially etched track holes. The tracks are then counted at the voltage corresponding to the plateau region of the counter (450 V).The concentrations are derived from the observed track densities using appropriate calibration factors. The calibration factors depend upon various parameters such as membrane and characteristics as well as the energy of the alpha particles for the cup mode exposure, the parameters of the etching process, and spark counting characteristics.

From track density radon and thoron concentrations were calculated using the sensitivity factor determined from the controlled experiments. The concentrations of radon (C_R) and thoron (C_T) were calculated by using the following relations (Sannapa et al, 2003; Mayaya et al; 1988):

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

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

Where,

C_R = Radon concentration

C_T = Thoron concentration

T_m = Track density in membrane compartment

T_f = track density in filter compartment

D = Exposure time

Sensitivity factor for membrane compartment (S_m) = 0.019±0.003 $Tcm^{-2}d^{-1}/Bqm^{-3}$

Sensitivity factor for radon in filter compartments (S_{rf}) = 0.020±0.004 $Tcm^{-2}d^{-1}/Bqm^{-3}$

Sensitivity factor for thoron in filter compartment (S_{tf}) = 0.016±0.005 $Tcm^{-2}d^{-1}/Bqm^{-3}$

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 indoor radon, thoron and annual effective dose rates in the some dwellings of Jaipur City, Rajasthan.Radon concentrations was found to vary from 35.1 ± 4.5 Bq m^{-3} to 84.8 ± 7.0 Bq m^{-3} with an average value of 59.0 ± 5.9 Bq m^{-3}, Thoron concentrations was found to vary from 3.5 ± 0.3 Bq m^{-3} to 24.3 ± 2.2 Bq m^{-3} with an average value of 13.7 ± 1.3 Bq m^{-3}. The annual effective dose due to the exposure to indoor radon and progeny are found to vary from 1.02 to 2.46 mSv. However, the annual effective dose due to the exposure to thoron and progeny was found to vary from 0.09 to 0.61 mSv.

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.

Table.1 Radon, thoron and annual effective dose rates in the some dwellings of Jaipur City, Rajasthan

Houses	Indoor concentration (Bq m^{-3})		Annual efeectrive dose (mSv)	
	Radon	Thoron	Radon	Thoron
House no.-1	52.6 ± 5.5	10.5 ±1.0	1.52	0.26
House no.-2	55.5 ± 5.7	3.5 ± 0.3	1.60	0.09
House no.-3	58.5 ± 5.8	10.4 ± 0.9	1.70	0.26
House no.-4	59.6 ± 5.9	17.4 ±1.5	1.72	0.43
House no.-5	49.7 ± 5.4	24.3 ± 2.2	1.44	0.61
House no.-6	62.0 ±8.0	16.6 ± 1.4	1.80	0.41
House no.-7	64.3 ± 6.1	18.8 ± 1.6	1.86	0.47
House no.-8	73.1 ± 6.5	13.9 ± 1.5	2.12	0.35
House no.-9	63.1 ± 6.1	11.2 ± 1.0	1.83	0.28
House no.-10	70.2 ± 6.4	13.8 ± 1.1	2.03	0.35
House no.-11	78.9 ± 6.8	13.9 ± 1.1	2.29	0.28
House no.-12	68.4 ± 6.3	12.5 ± 1.1	1.98	0.31
House no.-13	84.8 ± 7.0	10.4 ± 0.8	2.46	0.26
House no.-14	43.8 ± 5.0	23.7 ± 2.3	1.27	0.60
House no.-15	47.9 ± 5.3	9.7 ± 1.0	1.39	0.24
House no.-16	35.1 ± 4.5	11.1 ± 1.3	1.02	0.28
House no.-17	51.5 ± 5.5	11.8 ± 1.1	1.49	0.30
House no.-18	42.1 ± 5.0	12.5 ± 1.3	1.22	0.31
Minimum value	35.1 ± 4.5	3.5 ± 0.3	1.02	0.09
Maximum value	84.8 ± 7.0	24.3 ± 2.2	2.46	0.61
Average value	59.0 ± 5.9	13.7 ± 1.3	1.70	0.33
S. D.	12.8 ± 0.8	4.9 ± 0.5	0.37	0.12

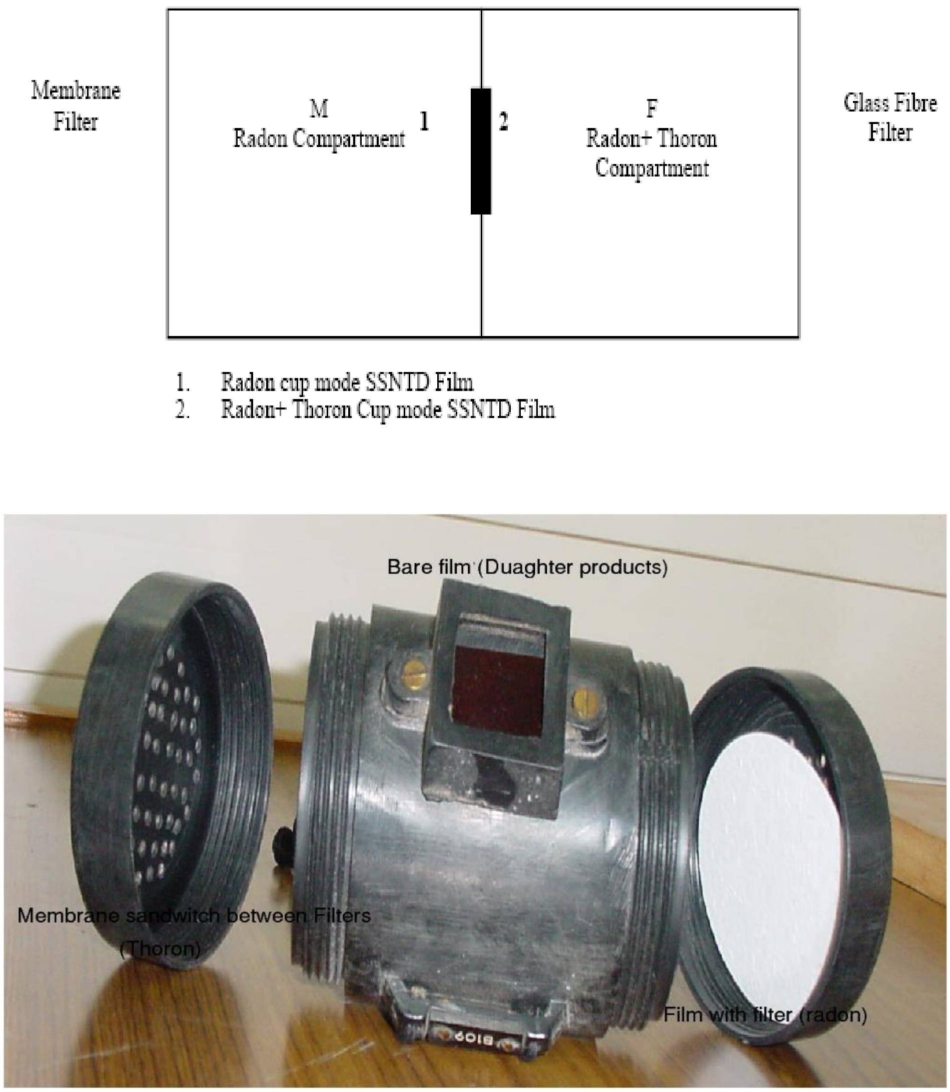

Figure.1 Schematic diagram and photograph of radon- thoron twin chamber dosimeter cup

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.

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

Acknowledgements

One of the author A. K. Mahur wish to thank to Dr. Mukesh Kumar S. V. College , Aligarh for providing the facilities for analysis this work and also thankful to the residents of the study area for their cooperation during the field work. Sincere thanks are also due to Dr. Kanji Lal, Director Inter-University Accelerator Centre, New Delhi for providing spark counting system for analysis the radon/thoron and constant encouragement.

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