Dynamics of Thoron Concentration in Dwellings of the Industrial Sites in Kannur District, Kerala

Neeraja N[1], Sahadiya Nazar[2], Nadira Mahamood K[2], Prakash, V[1*]

[1] Department of PG Studies & Research in Physics, Payyanur College, Edat - 670327, India

[2] Department of PG Studies in Physics, Sir Syed College, Taliparamba - 670142, India

E-mail: *prakashamv@gmail.com (corresponding author)

Abstract: *The current study deals with the evaluation of the indoor concentration of ^{220}Rn (thoron) in different dwellings with various construction materials used for the roof and floor in the major industrial sites of Kannur district, Kerala. A pinhole-based dosimeter coupled with LR-115 Solid State Nuclear Track Detector (SSNTD) and Direct Thoron Progeny Sensor (DTPS) were respectively used for the measurement of indoor concentration and equilibrium equivalent concentration of thoron. The thoron concentrations were found to vary from 124.64 Bqm^{-3} - 453.65 Bqm^{-3}. The annual effective doses and excess lifetime cancer risks were observed in the range of 3.144 mSvy^{-1} -11.4 mSvy^{-1} and 13x10^{-3} to 45x10^{-3} respectively, and both exceeded the world average values recommended by UNSCEAR 2000. The study shows that, the houses with marble floor and concrete roof have comparatively higher values of thoron concentration, which indicates the significant contribution of construction materials to the enhanced radiation levels inside the dwellings.*

Key Words: *Indoor Thoron Concentration, Annual Effective Dose, Excess Lifetime Cancer Risk, Pinhole-Based Dosimeter, Direct Thoron Progeny Sensor (DTPS), Equilibrium Equivalent Concentration.*

1. Introduction

The radionuclides from the decay series of ^{232}Th and ^{238}U are the major contributors to the terrestrial gamma radiation in the environment. Among those radionuclides, ^{220}Rn (thoron) from the decay chain of ^{232}Th is known to be hazardous due to various characteristics of the radionuclide. The radioactive gas emanating from ^{220}Rn can cause severe health issues including lung cancer, leukemia, etc. as per various reports. In view of this, here is an attempt to probe the ^{220}Rn activity concentration in dwellings near industrial sites in Kannur district, Kerala. The dwellings were categorized depending on the various materials used for construction.

2. Methodology

A pinhole based dosimeter mounted with an LR-115 type Solid State Nuclear Track Detector (SSNTD) and Direct Thoron Progeny Sensors (DTPS) respectively was used to measure the indoor thoron concentration (in Bqm^{-3}) (Kirandeepkaur, et al., 2017) and equilibrium equivalent thoron concentration (in Bqm^{-3}) (Mishra, R. and Mayya, Y.S., 2008; Prabhjot Singh, et al., 2015). Both the dosimeters were placed in different types of dwellings categorized as; Mud House (MH), Tile floor and Concrete roof (TC), Odu and wood roof and Red oxide floor (OR), Granite floor and Concrete roof (GC), and Marble floor and Concrete roof (MC). After the 3 months (90 days) of exposure time, the exposed SSNTD films were etched with 2.5N NaOH solution at a temperature of 60ºC in a water bath for 90 minutes. The track density (in $Trcm^{-2}d^{-1}$) of alpha particles was then counted using a spark counter. The indoor thoron concentration and equilibrium equivalent concentration (EEC) were measured, and radiological parameters such as the annual effective dose (in mSv), excess lifetime cancer risk (ELCR) were estimated.

The indoor thoron concentration, C_T in Bqm^{-3} in the dwellings was estimated using the equation;

$$C_T\ (Bqm^{-3}) = \frac{(T_2 - B) - (T_1 - B)}{d \times K_T} \qquad (1)$$

Where, T_1 and T_2 represent the track densities of radon and radon+thoron respectively in $Trcm^{-2}$observed in the spark counter, B is the track density recorded in the unexposed sensors, K_T is the calibration factor of thoron in radon+thoron chamber, $K_T = 0.010\ Trcm^{-2} d^{-1}$ per Bqm^{-3} and d is the exposure time of the SSNTD films, d = 90 days (Sudhir Mittal, et al., 2017).

The annual effective dose due to exposure to indoor radon and its progeny in $mSvy^{-1}$ is given by the equation;

$$AED_{indoor}\ (mSvy^{-1}) = C_T (Bqm^{-3}) \times 0.09 \times 0.8 \times 8760\ hy^{-1} \times 40\ nSvh^{-1} (Bqm^{-3})^{-1} \times 10^{-6} \qquad (2)$$

Where, C_T is the indoor thoron concentration in, Bqm^{-3} 0.09 is the indoor equilibrium factor between thoron and its progenies, $40\ nSvh^{-1}(Bqm^{-3})^{-1}$ is the dose conversion factor for thoron exposure, and 0.8 is the occupancy factor for indoor radiation (Kirandeepkaur, et al., 2017).

The excess lifetime cancer risk (ELCR) was calculated using the equation;

$$ELCR = AED_{indoor}\ (mSvy^{-1}) \times DL\ (y) \times RF\ (Sv^{-1}) \quad (3)$$

Where, DL is the duration of life (70 years) and RF is the risk factor $(0.05\ Sv^{-1})$ recommended by the ICRP.

The equilibrium equivalent concentration of thoron (EEC_{Rn-220}) in Bqm^{-3} measured using DTPS can be calculated using the equation;

$$EEC_{Rn-220} = \frac{T_{DTPS} - B}{d \times S_{Rn}} \quad (4)$$

Where, T_{DTPS} in $Trcm^{-2}$ in is the track density of alpha particles in the thoron exposed sensors, B is the track density recorded in the unexposed sensors, d is the no. of days for which the sensors were exposed to radiation and S_{Rn} is the sensitivity factor of thoron, which is equal to

$0.94\ Trcm^{-2}d^{-1}(Bqm^{-3})^{-1}$(Sumit Sharma, et al., 2008).

3. Result and Discussion

The indoor thoron activity concentration in dwellings varies from 125 Bqm^{-3} - 454 Bqm^{-3}. The values estimated for different houses clearly indicate that thoron activity concentration varies significantly with the type of house. The contributing factors may be ventilation conditions, types of construction, materials used for construction, and site specific characteristics. The maximum concentration of 454 Bqm^{-3} (track density of 409 $Trcm^{-2}d^{-1}$) observed in dwellings with marble floor and concrete roof. The poor ventilation and cracks in floor due to age might be contributed to the higher level of activity concentration, in addition to the considerable role of construction materials. The marble floor house followed by granite floor house with activity concentration of 288 Bqm^{-3}. Granite is a natural source of radiation, like most natural stones. The minimum concentration of 125 Bqm^{-3}(track density of 113 $Trcm^{-2}d^{-1}$) observed in mud house with good ventilation. The annual effective dose in the dwellings ranges from 3mSv to11mSv with the observed maximum for the marble floor and concrete roof house. Based upon calculated values of annual effective dose, excess lifetime cancer risk (*ELCR*) was calculated and found to vary from $13x10^{-3}$ to $45x10^{-3}$. The thoron progeny concentration (in Bqm^{-3}), annual effective dose (in $mSvy^{-1}$) and excess lifetime cancer risk for different houses under study are given in Table 1.

Table 1: Indoor Thoron Concentration in Different Types of Houses

Type of house	Track density T_1 ($Trcm^{-2}$)	Track density T_2 ($Trcm^{-2}$)	Thoron concentration (Bqm^{-3})	Average thoron concentration (Bqm^{-3})	Annual effective dose ($mSvy^{-1}$)	Excess lifetime cancer risk (x 10^{-3})
MH1	242.5	30.5	33.8	124.64	3.144	12.544
MH2	164.25	195.75	215.40			
TC1	275.75	189	210	215.97	5.44	21.705
TC2	300.5	149.75	221.94			
OR1	286.75	321.25	356.9	273.033	6.88	27.483
OR2	157.5	170.25	189.167			
GC1	338.25	261.5	290.5	287.89	7.263	28.978
GC2	309.75	256.75	285.28			
MC1	228	689.5	765.4	453.65	11.4	45.64
MC2	434	127.75	141.9			

The track density associated with DTPS varies from 48 $Trcm^{-2}d^{-1}$ to 268 $Trcm^{-2}d^{-1}$. The equilibrium equivalent thoron concentration ($EETC_{Rn-220}$) varies from 0.033 Bqm^{-3} to 2.63 Bqm^{-3} with observed minimum value for granite floor with concrete roof house and maximum value for mud house. The equilibrium equivalent concentrations of thoron in different types of houses are given in Table 2.

Table 2: Equilibrium Equivalent Concentration of Thoron in Different Types of Houses

Type of house	Track density T_{DTPS} ($Trcm^{-2}$)	Average track density ($Trcm^{-2}$)	Equilibrium equivalent concentration (Bqm^{-3})
MH1	310.25	267.5	2.63
MH2	224.75		
TC1	71.75	74.625	0.35
TC2	77.5		
OR1	172.75	153.125	1.27
OR2	133.5		
GC1	42.75	47.875	0.033
GC2	53		
MC1	46.25	50.875	0.069
MC2	53.75		

Conclusion

The higher concentration observed in the houses with marble/granite floor and concrete roof and the lower concentration in mud houses clearly indicate the substantial contribution of construction material and type of construction in the enrichment of thoron activity. The concentration might also be affected by climatic conditions, human interference, and site specific characteristics. The estimated annual effective dose and *ELCR* values are higher than the world's average, indicating an additional risk of getting cancer due to occupancy inside the dwellings for a longer time.

Reference

Kirandeepkaur, Manmohan Singh Heer, Rohit Mehra, Sahota, H.S. (2017), Measurement of Indoor Radon and Thoron Using Single Entry Pin-Hole Dosimeters in the Dwellings of Bathinda District of Punjab, India, *International Journal of Pure and Applied Physics*, 13(1): 65-70.

Mishra, R. and Mayya, Y.S. (2008). Study of a Deposition Based Direct Thoron Progeny Sensor (DTPS) for Estimating Equilibrium Equivalent Thoron Concentration (EETC) in Indoor Environment, *Radiation Measurements*, 43(8): 1408-1416.

Prabhjot Singh, Parminder Singh, Surinder Singh, Sahoo, B.K., Sapra, B.K., Bajwa, B.S. (2015). A Study of Indoor Radon, Thoron and Their Progeny Measurement in Tosham Region Haryana, India, *Journal of Radiation on Research and Applied Sciences*, 8: 226-233.

Sudhir Mittal, Asha Rani, Rohit Mehra, Sahoo, B.K., Sapra, B.K. (2017). Radiological Variation of Indoor Radon and Thoron Levels by Pinhole Dosimeter in Different Seasons, *Indoor Built Environ*., 1-14.

Sumit Sharma, Ajay Kumar, Rohit Mehra, Manpreet Kaur, Rosaline Mishra (2018). Assessment of Progeny Concentrations of 222Rn/220Rn and Their Related Doses Using Deposition-Based Direct Progeny Sensors, *Environ. Sci. Pollut. Res.*, 25: 11440–11453.