Iran. J. Radiat. Res., 2009; 7 (2): 79-84

Seasonal variation of radon, thoron and their progeny levels in dwellings of Haryana and Western Uttar Pradesh

K. Kant[1*], Rashmi[2], R.G. Sonkawade[3], G.S. Sharma[4], R.P. Chauhan[5], S.K. Chakarvarti[5]

1Aggarwal College, Ballabgarh, Faridabad, 121 004; Formerly at Department of Physics, KL Mehta DN College for Women, Faridabad, Haryana, 121 001, India
[2]Department of Physics, GFITM, Ballabgarh, Faridabad, Haryana, India
[3]Inter University Accelerator Centre, New Delhi, 110 067, India
[4]Department of Physics, G.L.A. Institute of Technology and Management, Mathura (U.P) 281 001, India
[5]Department of Applied Physics, NIT, Kurukshetra, 136 119, India

Background: Radon and thoron are invisible, odorless, heavy and radioactive gases which are ubiquitously present in dwellings and in the environment. In the present work, seasonal variation of indoor radon, thoron and their progeny concentrations has been studied in the dwellings of industrially polluted cities in District Faridabad, Haryana and District Mathura in Uttar Pradesh. ***Materials and Methods:*** LR -115, Type- II (Kodak Pathe, France), peelable, plastic track detectors commonly known as solid state nuclear track detectors (SSNTDs) were used to measure the radon thoron concentration over long integrated times. The measurements were carried out in the mixed field of radon and thoron and the detectors were exposed for about 90 days. ***Results:*** The average value of radon and thoron concentration in the dwellings varied from 23.5 Bq/m^3 to 65.2 Bq/m^3 and 9.8 Bq/m^3 to 18.7 Bq/m^3 respectively in different seasons. The average annual exposure and annual effective dose in living rooms due to radon and thoron progeny was estimated to be 0.195 WLM (working level month) and 0.74 mSv respectively. The average life time fatality risk of lung cancer from the chronic radon and thoron progeny exposure was estimated to be 5.8 ´ 10^{-3} (0.58%). ***Conclusion:*** The seasonal variations of measured radon levels in the environment of LPG bottling plant, radon-thoron levels and inhalation dose due to radon and thoron and their progeny in dwellings indicate that the levels were higher in winter (October to January) than in summer (April to July). **Iran. J. Radiat. Res., 2009; 7 (2): 79-84**

Keywords: *Indoor radon, thoron, progeny, exposure, etching, inhalation dose.*

INTRODUCTION

Radon, thoron and their progenies present in the environment contribute the maximum of the natural radiation dose to the occupational workers and general public. Elevated levels of radon in the indoor environment and environment of work places in many countries have been realized as a concern of public health and hygiene and there has been a keen interest in studies related to monitoring of radon and the inhalation dose to the public living in that environment [(1)]. In earlier reports, it was assumed that the contribution from thoron and its progeny is about 10% of that of radon and its progeny, and hence this component was ignored while measuring radon concentration and calculating the inhalation dose due to alpha active air pollutants [(1)]. But recent studies have shown that the contribution of thoron and its progeny is not trivial and forms a significant quantum of the indoor inhalation dose rates, sometimes even more than that of radon and its progeny particularly at places where thorium deposits are found and even in mines [(2-10)]. There have been reports of radon-thoron levels in various states in India [(11)]. For a vast country like India with different meteorological and geological conditions, the data remains scanty and there is a need to generate comprehensive region wise database so that the data can be

Corresponding author:
Dr. Krishan Kant,
Aggarwal College, Ballabgarh, Faridabad, 121 004 and, Department of Physics, KL Mehta DN College for Women, Faridabad, Haryana, 121 001, India.
E-mail: *kkant_67@rediffmail.com*

[Downloaded from ijrr.com on 2026-11-28]

pooled to have a more significant results about radon-thoron levels and inhalation dose rates. In the present work, we report on the seasonal variation of radon-thoron and their progeny levels in the dwellings in South Haryana and Western U.P, besides LPG bottling plant in Haryana. There are various natural and man made sources of radiation in these areas, like refinery, thermal power plant, geothermal springs, slate mines, industrial zones, aravali range etc., due to which it is very important to carry out a systematic study of radon-thoron levels in the dwellings from the health and hygiene point of view of the occupants.

MATERIALS AND METHODS

Experimental Methods

The Radon and thoron measurements were carried out using LR-115 plastic track detector (Solid State Nuclear Track Detectors) exposed in the mixed field of radon-thoron in the environment of LPG bottling plant. It consists of a 12-13 μm thick alpha-sensitive layer of red dyed cellulose nitrate plastic deposited on a 100 μm thick non etchable polyester base. It is sensitive to alpha particles with energies in the range of 1.7-4.2 MeV emitted by radon in the surrounding air for a distance of 1-6 cm. The LR-115 detectors were used in view of the fact that LR-115 detectors do not develop tracks originating from the progeny alphas deposited on them and are therefore best suited for alpha radioactive measurements in the ambient air [12-13].

The dosimeter employed for the measurement consists of twin chamber system with SSNTDs placed on the two sides of the central partition inside the cup and a bare film placed outside it as shown in figure 1 and details discussed elsewhere [14]. Each chamber has a length of 4.5cm and a radius of 3.1cm. The LR-115 film was fixed in the dosimeter system and mounted at the same place and the standard etching procedure specified by the manufacturer has been followed for the same. The etched films after removal of the base were recorded for its track density using the well calibrated spark counter design characteristics are similar to the one discussed by Garakani [15].

RESULTS AND DISCUSSION

Radon, thoron and their progeny dosimetry

From the 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 [16, 17].

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

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

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 (100days)

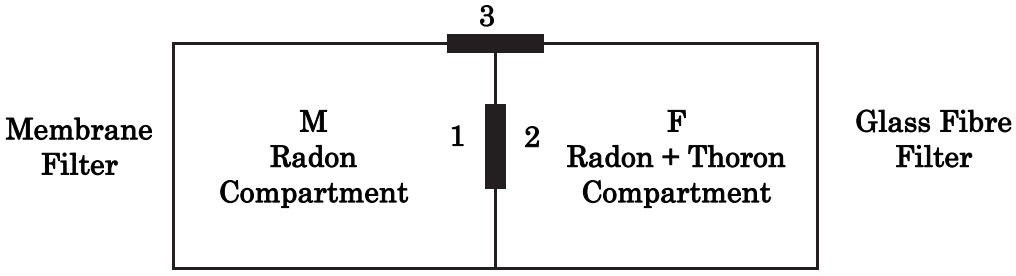

Figure 1. Radon-Thoron mixed field dosimeter System.

[Downloaded from ijrr.com on 2026-11-28]

Sensitivity factor for membrane compartment (S_m) = 0.019 ± 0.003 $Trcm^{-2}d^{-1}/Bqm^{-3}$
Sensitivity factor for radon in filter compartment (S_{rf}) = 0.020 ± 0.004 $Trcm^{-2}d^{-1}/Bqm^{-3}$
Sensitivity factor for thoron in filter compartment (S_{tf}) = 0.016 ± 0.005 $Trcm^{-2}d^{-1}/Bqm^{-3}$
The inhalation dose in mSv/y was estimated using the formula.

$$D = \{(0.17 + 9F_R)\, C_R + (0.11 + 32F_T)\, C_T\} \times 7000 \times 10^{-6} \quad (3)$$

The values of radon-thoron levels and their seasonal variation in the dwellings in western U.P. and South Haryana are given in table 1. It reveals from the table that the average value of radon and thoron concentration varies from 23.5 Bq/m^3 to 65.2 Bq/m^3 and 9.8 Bq/m^3 to 18.7 Bq/m^3 respectively in different seasons. The minimum, maximum and average value of annual inhalation dose due to radon, thoron and their progeny and their seasonal variation is shown in figure 2. The inhalation dose was found to be more in the dwellings in District Faridabad than in Mathura. This was probably due to the fact that Faridabad is an industrial hub and lots of industries using fossil fuels are in operation here, besides a thermal power plant. The seasonal variation of radon levels in the environment of LPG bottling plant is shown in figure 3.

Radon and thoron daughters dosimetr

From the obtained values of radon and thoron, the seasonal variation of daughter concentration of radon, thoron in terms of (PAEC) potential alpha energy concentration (mWL), annual exposure in (WLM), were calculated and the values are given in table 2 and 3 respectively. The measured radon/thoron PAEC was converted into radon concentration using the formula

$$C_R \text{ or } C_T\ (Bq/m^3) = \text{PAEC (WL)} \times 3700/F \quad (4)$$

Where F is equilibrium factor and its value is 0.4 and 0.1 for radon and thoron,

Table 1. Seasonal variation of indoor radon and thoron levels in dwellings.

Sr. No.	*Concentration*	*Radon conc. (Bq/m^3) Winter*	*Autumn*	*Summer*	*Rainy*	*Thoron conc. (Bq/m^3) Winter*	*Autumn*	*Summer*	*Rainy*
1.	***Minimum***	40.7	22.3	31.2	19.8	6.3	3.1	4.7	2.5
2	***Maximum***	80.6	46.8	54.2	29.7	27.2	17.1	19.6	12.3
3	***Average Value***	65.2	32.6	40.2	23.5	18.7	14.3	12.2	9.8

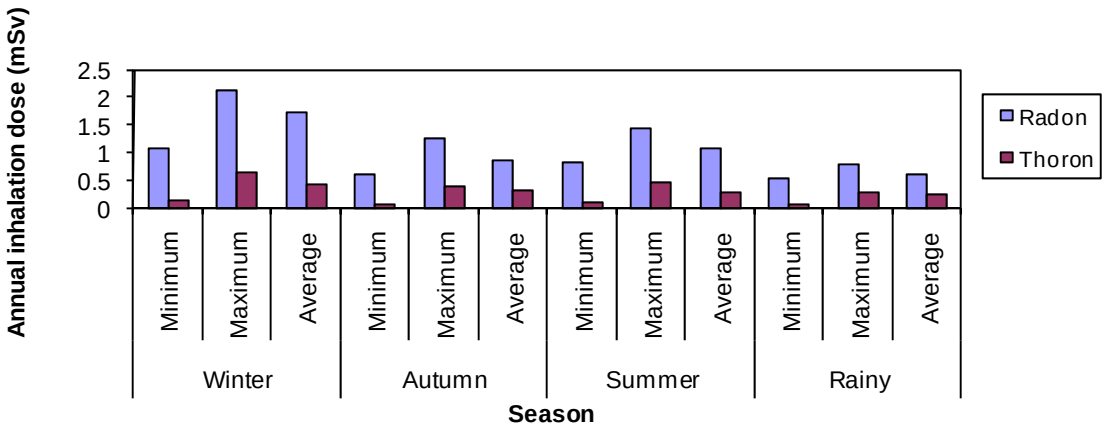

Figure 2. Seasonal variation of annual inhalation dose due to radon and its progeny and thoron and its progeny.

[Downloaded from ijrr.com on 2026-11-28]

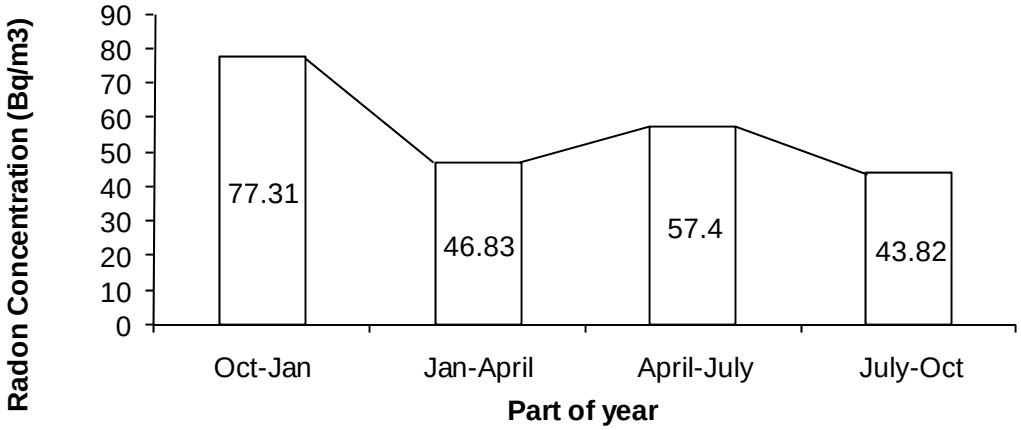

Figure 3. Seasonal variation of radon levels in the environment of LPG bottling plant.

respectively as given in UNSCEAR report [18]. Annual exposure due to radon and its progeny have been calculated by using the generic relations given in the report of ICRP [19]. The exposure due to radon and thoron daughters was calculated on seasonal basis and the annual exposure was calculated by taking the sum for all the four seasons. The annual exposure due to radon and thoron, lifetime fatality risks and annual effective dose were calculated and the results are given in table 4. The PAEC was converted into annual effective dose by using dose conversion factors; the radon daughter dose conversion factor for members of the public is 3.88 mSv per WLM as recommended by ICRP [20], where as the effective dose equivalent for thoron is 3.4 mSv per WLM as recommended by UNSCEAR [21].The lifetime risk associated with indoor radon exposure was calculated by using 1 WLM = 10×10^{-6} cases/year. If the risk persists for 30 years, Life time fatality risk = 3×10^{-4} cases/WLM [22].

Table 2 shows that the minimum, maximum and average concentration of radon daughters varied from 4.39 mWL to 8.70 mWL with an average value of 7.04 mWL in winter, 2.41 mWL to 5.05 mWL with an average value of 3.52 mWL in autumn, 3.37 mWL to 5.85 mWL with an average value of 4.34 mWL in summer, 2.14 mWL to 3.21 mWL with an average value of 2.54 mWL in rainy season, and for thoron daughters varied from 0.17 mWL to 0.73 mWL with an average value of 0.50 mWL in winter, 0.08 mWL to 0.46 mWL with an average value of 0.38 mWL in autumn, 0.13 mWL to 0.53 mWL with an average value of 0.33 mWL in summer, 0.06 mWL to 0.33 mWL with an average value of 0.26 mWL in rainy season.

Table 3 shows that the minimum, maximum and average value of exposure from radon daughters varied from 0.045 WLM to 0.089 WLM with an average value of 0.073 WLM in winter, 0.025 WLM to 0.052 WLM with an average value of 0.036 WLM in autumn, 0.035 WLM to 0.060 WLM with an average value of 0.045 WLM in summer, 0.022 WLM to 0.033 WLM with an average value of 0.026 WLM in rainy season and for thoron daughters varied from 1.74×10^{-3} WLM to 7.45×10^{-3} WLM with an average value of 5.10×10^{-3} WLM in winter, 0.81×10^{-3} WLM to 4.70×10^{-3} WLM with an average value of 3.88×10^{-3} WLM in autumn, 1.32×10^{-3} WLM to 5.41×10^{-3} WLM with an average value of 3.37×10^{-3} WLM in summer, 0.61×10^{-3} WLM to 3.37×10^{-3} WLM with an average value of 2.65×10^{-3} WLM in rainy season.

Table 4 shows that the minimum, maximum and average value of annual exposure from radon and thoron daughters varied from 0.127 WLM to 0.237 WLM with an average value of 0.180 WLM, the life time fatality risk varied from 0.39×10^{-4} to 0.76×10^{-4} with an average value of 0.58×10^{-4} and the annual effective dose from

[Downloaded from ijrr.com on 2026-11-28]

Table 2. Seasonal variation of the potential alpha energy concentration (PAEC) of radon thoron daughters in dwellings.

Sr. No.	Concentration	PAEC due to radon (mWL) Winter	Autumn	Summer	Rainy	PAEC due to thoron (mWL) Winter	Autumn	Summer	Rainy
1	Minimum	4.39	2.41	3.37	2.14	0.17	0.08	0.13	0.06
2	Maximum	8.70	5.05	5.85	3.21	0.73	0.46	0.53	0.33
3	Average Value	7.04	3.52	4.34	2.54	0.50	0.38	0.33	0.26

Table 3. Seasonal variation of the annual exposure due to radon thoron daughters in dwellings.

Sr. No.	Values (WLM)	Exposure due to radon progeny (WLM) Winter	Autumn	Summer	Rainy	Exposure due to thoron progeny ($WLM \times 10^{-3}$) Winter	Autumn	Summer	Rainy
1	Minimum	0.045	0.025	0.035	0.022	1.74	0.81	1.32	0.61
2	Maximum	0.089	0.052	0.060	0.033	7.45	4.70	5.41	3.37
3	Average Value	0.073	0.036	0.045	0.026	5.10	3.88	3.37	2.65

Table 4. Radon and thoron daughters annual exposure (WLM), life time fatality risk factor and annual effective dose in the dwellings.

Sr. No.	Values	Annual exposure (Rn) (WLM)	Annual exposure (Tn) ($WLM \times 10^{-3}$)	Annual exposure (Rn + Tn) (WLM)	Life time fatality risk factor ($\times 10^{-4}$)	Annual effective dose (mSv)
1	Minimum	0.127	4.48	0.132	0.39	0.50
2	Maximum	0.234	20.93	0.255	0.76	0.98
3	Average	0.180	15	0.195	0.58	0.74

radon and thoron daughters varied from 0.50 mSv to 0.98 mSv with an average value of 0.74 mSv.

CONCLUSION

The seasonal variations of measured radon levels in the environment of LPG bottling plant, radon-thoron levels and inhalation dose due to radon and thoron and their progeny in dwellings indicate that the levels were higher in winter (October to January) than in summer (April to July). It is because the ventilation becomes poor in winter due to lower exchange rate of air. The decrease of radon concentration in monsoon season is due to the fact that the soil is saturated with water [22]. The average value of inhalation dose in certain dwellings is significantly higher than the Global average value [1].

In the light of these findings, the LPG bottling plants and the industries using fossil fuels may affect doses from external irradiation and the inhalation of radon decay products is significant from health point of view. Necessary steps should be taken to minimise the adverse effects on the environment from NORMs exposures through monitoring, safe work guidelines etc.

ACKNOWLEDGEMENTS

The authors are thankful to the residents of dwellings in District Faridabad

[Downloaded from ijrr.com on 2026-11-28]

(Haryana) and District Mathura (Uttar Pradesh) for allowing the detectors to be placed in their living rooms. The experimental support received from Mr. Amit Roy, The Director, IUAC, New Delhi is thankfully acknowledged.

REFERENCES

1. UNSCEAR (2000) United Nations Scientific Committee on the Effect of Atomic Radiation, *Sources and Effects of Ionizing Radiation*, United Nations, New York.
2. Guo Q, Shimo M, Ikebe Y, Minato S (1992) The study of thoron and radon progeny concentrations in dwellings in Japan. *Radiat Prot Dosim*, ***45:*** *357-359.*
3. Ramachandran TV, Eappen KP, Mayya YS (2002) *Measurement of Thoron Levels in Dwellings using Solid State Nuclear Track Detector Technique, in proceedings of 21st Int Conf on Nuclear Tracks in Solids,* Oct. 21-25 New Delhi.
4. Sonkawade RG, Ramola RC, Kant K, Kanjilal DK, Dhiaryawan MP and Gupta P (2005) Dosimetry in the environment of 15 UD Pelletron accelerator using plastic track detectors. *Rad Protection and Environment*, ***28:*** *156-159.*
5. Abraham JP, Rajagopalan M, Sukesh Kamath S, Chithra S (2005) Distribution of indoor radon and thoron progeny levels in West Kochi Area, Kerela. *Env Geochemistry*, ***8:*** *286-289.*
6. Marcia PC, Brigitte RS, Simone A, Barbara PM (2006) Thoron exposure among tour guides in southern Brazilian show caves. *International J Low Radiation*, ***3:*** *217-223.*
7. Deka PC, Sarkar S, Goswami TD, Sarma BK (2006) Study of indoor radon, thoron and their progeny concentration levels in the surrounding areas of Mangaldoi, Assam. *Chemical and Environmental Research*, ***15:*** *292-305.*
8. Reddy BS, Reddy ChG, Reddy PY, Reddy KR (2006) Radon and thoron equilibrium factors for the dwellings of Khamman District, Andhra Pradesh. Chemical and *Environmental Research,* ***15:*** *265-270.*
9. Kumar R and Prasad R (2007) Measurement of radon and its progeny levels in dwellings of Srivaikuntam, Tamilnadu. *Indian J Pure & Applied Physics*, ***45:*** *116-118.*
10. Steinhalsler F (1996) Environmental ^{220}Rn: a review. *Env International*, ***22:****1111-1123.*
11. BARC (2003) Bhabha Atomic Research Centre*, Radon-Thoron Levels and Inhalation Dose Distribution Patterns in Indian Dwellings* (ed. Ramachandran T. V. et al.) Report BARC/2003/E/026, p. 40.
12. Nikolaev VA and Ilic R (1999) Etched track radiometers in radon measurements: a review. *Radiat Meas*, ***30:*** *1-13.*
13. Durrani SA (1997) Radon Measurements by Etched Track Detectors: Application in Radiation Protection, Earth Sciences and the Environment (World Scientific, Singapore), p. 77.
14. Eappen KP and Mayya YS (2004) Calibration factor for LR-115 (type-II) based radon thoron discriminating dosimeter. *Radiat Meas*, ***38:*** *5-17.*
15. Garakani DA (1989) Spark counter for alpha particle registration, *in proceedings of the International Workshop on Radon Monitoring in Radioprotection, Environmental Radioactivity and Earth Sciences,* (eds) L Tomassino, G Surlan, H A Khan and M Monnin (Singapore; World Scientific), p.164.
16. *Mayya YS, Eappen KP, Nambi KSV (1998) Methodology for mixed field inhalation dosimetry in Monizite areas using a Twin-Cup Dosimeter with three track detectors. Radiation Protection Dosimetry,* ***77:*** *177-184.*
17. Sannappa J, Chandrashekara MS, Sathish LA, Paramesh L, Venkataramaiah P (2003). Study of background radiation dose in Mysore city, Karnataka State, India. *Radiat Meas*, ***37:*** *55-65.*
18. UNSCEAR (1999) United Nations Scientific Committee on the Effect of Atomic Radiation, *Sources and Effects of Ionizing Radiation*, United Nations, New York.
19. ICRP (1981) International Commission on Radiological Protection, *Limits for inhaled radionuclides by workers*, ICRP publication 32, (Pergamon Press, Oxford).
20. ICRP (1993) International Commission on Radiological Protection. *Protection against radon-222 at home and at work*. ICRP Publication No. 65, (Pergamon Press, Oxford).
21. UNSCEAR (1993) United Nations Scientific Committee of the Effect of Atomic Radiation. *Sources and Effects of Ionizing Radiation*, Report to the General Assembly, Annex A, United Nations, New York.
22. Grasty RL (1994) Summer outdoor radon variations in Canada and their relations to soil moisture. *Health Physics*, ***66:****185-193.*

[Downloaded from ijrr.com on 2026-11-28]