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Environmental Monitoring of Radon-Thoron Levels and Their Seasonal Variation in Some Selected Dwellings in and Around Rampur City Using Solid State Nuclear Track Detector (SSNTD)

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Abstract
Monitoring of indoor radon, thoron and their progeny concentration were carried out in some selected dwellings in and around Rampur city of Uttar Pradesh (India) by using Solid State Nuclear Track Detector (SSNTD).The radon-thoron twin dosimeter cups are used for the study. The annual effective dose, annual exposure due to radon-thoron progeny and life time fatality risk factor under study have also been calculated. In the present study, it is found that the annual value of radon and thoron concentration varies from 18.80Bq/m^3 to 45Bq/m^3 and 10.90Bq/m^3 to 21.20Bq/m^3 respectively in different seasons, where as the value of radon progeny and thoron progeny concentration varies from 2.02mWL to 4.85mWL and 0.29mWL to 0.57mWL respectively in different seasons. The annual inhalation dose varies from 0.75mSv/y to 1.61mSv/y with an average value 1.15 mSv/y.The total annual exposure varies from 0.095WLM to 0.181 WLM with an average of 0.140WLM. The life time fatality risk of the residents of the study area ranges from 0.31×10^{-4} to 0.54×10^{-4} with an average value of 0.42×10^{-4}. The annual effective dose varies from 0.37mSy/y to 0.70 mSv/y with an average value of 0.54 mSv/y.

Keywords: Indoor radon-thoron concentration, annual effective dose**,** Solid state nuclear track detector, annual exposure, nuclear tracks.

I. Introduction

Studies on natural radioactivity and natural environmental radiations are of great importance as they are of interest in health physics, radiation physics and all the allied branches of natural science. The measurement of indoor radon/thoron and their progeny concentration in indoor atmosphere has been the interest of many research scientists all over the world. Radon and its short-lived decay products in the environment play the most important role to human exposure from natural sources of radiation. Radon is a naturally available radioactive gas, which is the decay product of radium. The possibility of cancer induction due to indoor radon has been attracting attention in the scientific community during the past decades. It is now wieldy recognized that indoor radon is a largest single source of exposure to ionizing radiation in the environment. For the population as a whole, the average effective radiation dose from radon is estimated to the greater than the dose from all other natural sources of radiation combined, greater than the dose from industrial activities including nuclear power and the dose from medical treatments including x-ray. It is well known that inhalation of the short-lived decay products of radon and to a lesser extent the decay products of thoron and their subsequent deposition along the walls of various airways of the bronchial tree, provides the main pathway for radiation exposure to the lungs(ICRP,1993; UNSCEAR,1993). Indoor radon, thoron and its decay products is assumed to be health hazardous for human. As these are inert gases therefore it can easily disperse into the environment as soon as it is released. About 90% of average radiation dose received by human from natural sources and about 50% is due to inhalation of radon, thoron and their progeny present in the dwellings (UNSCEAR, 2000.).Studies from different parts of the world show that the well-planned and systematic measurements of indoor radon/thoron activity concentrations for all seasons during a calendar year are necessary to calculate the actual dose due to exposure to indoor radon/thoron.The activity concentrations of indoor radon/thoron and their progeny are largely influenced by factors such as topography, type of house construction, building materials temperature, pressure, humidity, ventilation, wind speed, and even the life style of the people living in the house.(Jonassen, 1975; Martz et al.,1991; Nazaro and Doyle, 1985; Ramola et al., 1987, 1992, 1998, 2000; Segovia and Cejudo, 1984; Subba Ramu et al., 1998).To estimate the annual average equivalent dose, a number of indoor radon/thoron surveys have been carried out around the world.(UNSCEAR, 1993.)The aim of present work was to measure the indoor radon, thoron and their progeny concentration and then to calculate the inhalation dose, annual exposure due to radon and thoron progeny, life time fatality risk and annual effective dose.

II. Methodology

Twin cup radon dosimeter is used in present study for the measurement of indoor radon and thorn concentration. The exposure of the detector inside the cup is termed as cup mode and the one exposed open is termed as the bare mode. One of the cups has its entry covered with a glass fiber filter paper permeates both radon and thoron gases into the cup and is called the filter cup. The other cup is covered with a semi permeable membrane (Ward et al., 1977) sandwiched between two glass fiber filter papers and is called membrane cup. The radon-thoron mixed field dosimeter system is shown in figure 1.

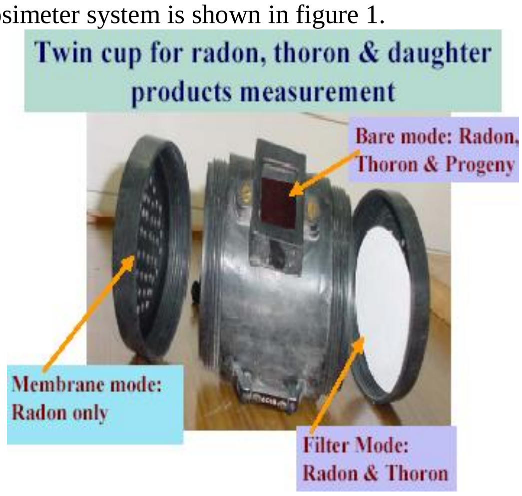

Figure 1.Radon-Thoron mixed field dosimeter system.

The SSNTD film (LR-115, Type II) inside the membrane cup registers tracks contributed by radon only, while that in the filter cup records due to radon and thoron. The third SSNTD film exposed in the bare mode registers alpha tracks contributed by the concentrations of both gases and their alpha emitting progeny. About 65 dosimeter were installed in different types of dwellings.The dosimeter is kept at a height of 2 m from the ground and care was taken to keep the bare card at least 10 cm away from any surface. This ensures the errors due to tracks from deposited activity from nearby surfaces are avoided, since the ranges of alpha particles from radon/thoron progeny fall within 10 cm distance.At the end of the stipulated period of exposure, usually about 90 days, the dosimeters are retrieved and all the three SSNTDs are etched with 2.5N NaOH solutions for 90 min. (Srivastava et al., 1995; Ramola et al., 1996, 1997, 2005; Miles, 1997; Ramachandran, 1998) at a bath temperature of about 60 °C. The track density of alphas in the film was determined using a spark counter. This exposure cycle has been extended in a time integrated four quarterly cycles to cover all the four seasons of a calendar year to evaluate the annual radon/thoron and their progeny levels. The radon/thoron levels and their progeny concentrations are calculated by the following relations (Mayya et al., 1998).

$$\mathbf{C_R\,(Bq/m^3) = T_m / d \times S_m} \qquad (1)$$

$$\mathbf{C_T\,(Bq/m^3) = T_f - d\,C_R \times S_{rf} / d \times S_{tf}} \qquad (2)$$

where T_m is track density of the film in membrane compartment, d is the Period of exposure(days), S_m is the Sensitivity factor of membrane compartment, T_f is the track density of the film in filter compartment, S_{rf} and S_{tf} are the sensitivity factor of radon and thoron in filter compartment, respectively. The numerical values of these factors are given as follows.

Sensitivity factor for membrane compartment

$$\mathbf{S_m = 0.019 \pm 0.003\ Tr.cm^{-2}d^{-1}/Bqm^{-3}} \qquad (3)$$

Sensitivity factor for radon in filter compartment

$$\mathbf{S_{rf} = 0.020 \pm 0.004\ Tr.cm^{-2}d^{-1}/Bqm^{-3}} \qquad (4)$$

Sensitivity factor for membrane compartment

$$\mathbf{S_{tf} = 0.016 \pm 0.005\ Tr.cm^{-2}d^{-1}/Bqm^{-3}} \qquad (5)$$

The inhalation dose was calculated (in mSvy-1) using the relation,

$$\mathbf{D_{in}\,(mSvy^{-1}) = \{C_R\,(0.17+9F_R) + C_T\,(0.11+32F_T)\} \times .007} \qquad (6)$$

The values of radon and thoron concentration and inhalation dose obtained by using relations 1,2, and 6 and are given in table1.From the obtained values of radon and thoron, the seasonal variation of progeny concentration of radon and thoron in terms of potential alpha energy concentration (PAEC) in mWL along with life time fatality risks were calculated and the values are in table 2.The obtained values of radon and thoron concentration was converted in to progeny concentration(or Potential Alpha Energy Concentration) by using the formula

$$\mathbf{C_R \text{ or } C_T\,(Bq/m^3) = PAEC\,(mWL) \times 3700/F} \qquad (7)$$

Where F is the equilibrium factor having values are 0.4 and 0.1 for radon and thoron respectively. (UNSCEAR, 2000).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 Working Level Month (ICRP,1993), where as the effective dose equivalent for thoron is 3.4 mSv per WLM (ICRP, 1981).The annual exposure have been calculated through radon progeny by using (WLM= 36×WL).A factor $3 \times 10^{-4} WLM^{-1}$ was used to calculate the lifetime fatality risk (ICRP,1981).

Geography of the study area:

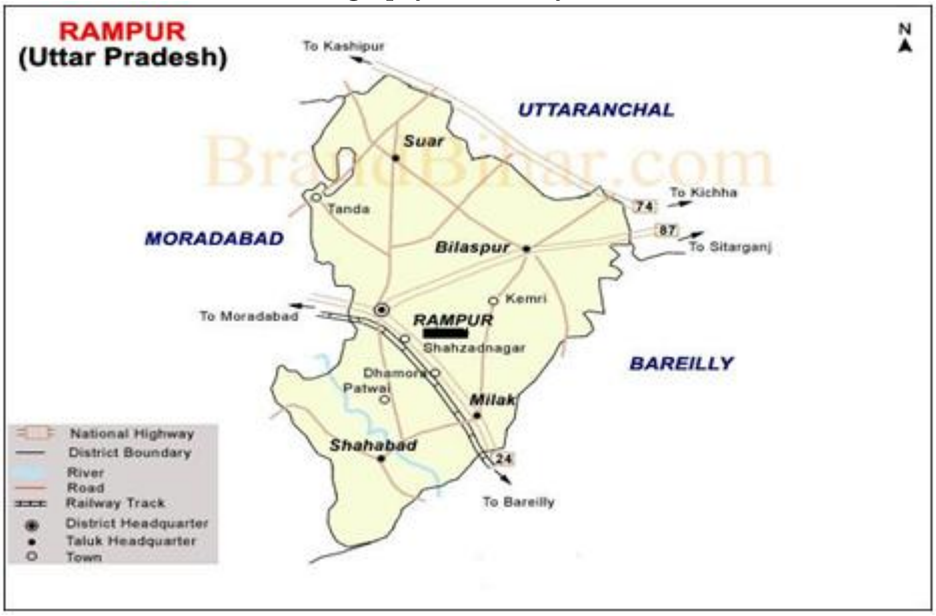

Figure 2. Map of Rampur District

Rampur is a city and headquarters of Rampur district in the Indian state of Uttar Pradesh. Uttar Pradesh is a state located in the northern part of India.Rampur, located between longitude79^{0}05′ E and latitude 28^{0}48′ N and spread in area of 2367 Sq.Km in Moradabad division of Uttar Pradesh. It is surrounded by District Udham Singh Nagar in North, Bareilly in East, Moradabad in West and Badaun in South. During rainy season just after a long period of rain the mountain ranges of Nanital can be seen in the north direction.Rampur is 192 meter above sea level in north and166.4 meter in south. Situated on the national highway 24, the state capital is 302 km in East and national capital is 185 km in West. It is well connected by Railways & Roadways. The district is part of Central Ganga Alluvial Plain and is represented by high slopes in the north, which gradually becomes flatter towards south. The climate is sub humid and it is characterized by a hot dry summer and winter. May is the hottest month and January is the coldest month of the year. The maximum temperature recorded in the month of May and June may be 46^{0}C. The selection of dwellings for installing dosimeters was done taking into account the degree of ventilation, type of floor, number of windows and doors as they all responsible for variation in indoor radon concentration.

III. Result and discussion

Measured values of radon-thoron concentration and radon-thoron progeny levels from different location in a four different seasons of a calendar year in Rampur District are given in table1.The minimum, maximum and average value of exposure due to radon-thoron progeny in the dwellings for a four different seasons of a calendar year is given in table 2, where as the minimum, maximum and average value of annual exposure, lifetime fatality risk annual effective dose and annual inhalation dose in the dwellings given is given in table 3. From the observation it is found that the values of radon concentration vary from 13Bq/m^3 to29Bq/m^3 with an average of 18.80Bq/m^3 in summer, 16.50Bq/m^3 to34Bq/m^3 with an average of 24.40Bq/m^3 in rainy, 6.0Bq/m^3 to38Bq/m^3 with an average of 30.20Bq/m^3 in autumn,29.50Bq/m^3 to78.30Bq/m^3 with an average of 45Bq/m^3 in winter, where as values of thoron concentration vary from 7Bq/m^3 to20Bq/m^3 with an average value of 10.90Bq/m^3 in summer, 8 Bq/m^3 to25Bq/m^3 with an average value of 15.50Bq/m^3 in rainy, 8.0Bq/m^3 to30Bq/m^3 with an average value of 16.50Bq/m^3 in autumn,10Bq/m^3 to41Bq/m^3 with an average value of 21.20Bq/m^3 in winter. The values of radon progeny concentration vary from 1.40mWL to 3.13mWL with an average value of 2.02mWL in summer, 1.78mWL to 3.67mWL with an average value of 2.63mWL in rainy, 0.60mWL to 4.10mWL with an average value of 3.26mWL in autumn, 3.18mWL to 8.45mWL with an average value of 4.85mWL in winter, where as he values of thoron progeny concentration vary from 0.18mWL to 0.54mWL with an average value of 0.29mWL in summer, 0.21mWL to 0.67mWL with an average value of 0.42mWL in rainy, 0.16mWL to 0.81mWL with an average value of 0.44mWL in autumn, 0.27mWL to 1.10mWL with an average of 0.57mWL in winter.

The value of exposure from radon progeny in the dwellings varied from 0.05WLM to 0.11WLM with an average value of 0.07 WLM in summer, 0.06WLM to 0.13WLM with an average value of 0.09WLM in rainy, 0.02WLM to 0.15WLM with an average value of 0.12WLM in autumn, 0.11WLM to 0.30mWLMwith an average value of 0.17WLM in winter, where as the value exposure from thoron progeny in the dwellings varied from 0.006WLM to 0.019WLM with an average value of 0.010WLM in summer, 0.008WLM to 0.024WLM with an average value of 0.015WLM in rainy, 0.005WLM to 0.029WLM with an average value of 0.016WLM in autumn, 0.009WLM to 0.039WLM with an average of 0.021WLM in winter.

The minimum, maximum and average value of annual exposure from radon and thoron (Rn+Tn) progenies varied from 0.095WLM to0.181WLM with an average value of 0.130 WLM, the life time fatality risk varied from 0.31×10^{-4} to 0.54×10^{-4} with an average value of 0.40×10^{-4} ,the annual effective dose ranges from 0.41mSv/y to 0.75mSv/y with an average value of 0.56mSv/y and the value of inhalation dose varies from 0.75mSv/y to 1.61mSv/y with an average of 1.15mSv/y.A graphical comparison between radon and thoron concentration, radon and thoron progeny concentration and annual exposure due to radon-thoron progeny are shown in figures 2,3 &4 respectively. The results shows quite higher radon and thoron levels in winter season as compared to the other season. This maximum concentration is essentially by the intense temperature inversion, which generally occurs in winter season when the wind velocity is low. The maximum concentration in winter is also the result of decreased ventilation because in this season the houses are closed for a long time and radon accumulated inside the room. The concentration of radon, thoron and their progeny levels in study area were observed below the recommended action level (200Bq/m^3) set by the various organizations (ICRP, 1993). All values obtained under the limit (ICRP, 1993), depending on the type of house construction, ventilation conditions and location. It is observed that at all the places the life time fatality risk factor, annual inhalation dose and annual effective dose is below the action level 3-10 mSv/y has been recommended by ICRP (ICRP, 1993).

Table 1.Seasonal variation of radon, thoron, radon progeny, and thoron progeny conc. in dwellings.

Season	**Radon (Bq/m^3)**			**Thoron (Bq/m^3)**			**Radon progeny (mWL)**			**Thoron progeny (mWL)**		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max	Avg.
Summer	13	29	18.8	7	20	10.9	1.40	3.13	2.02	0.18	0.54	0.29
Rainy	16.5	34	24.4	8	25	15.5	1.78	3.67	2.63	0.21	0.67	0.42
Autumn	6.0	38	30.2	8	30	16.5	0.60	4.10	3.26	0.16	0.81	0.44
Winter	29.5	78.3	45	10	41	21.2	3.18	8.45	4.85	0.27	1.10	0.57

Table 2. Seasonal variation of annual exposure due to radon and thoron progeny in dwellings

Season	**Exposure due to radon progeny (WLM)**			**Exposure due to thoron progeny (WLM)**		
	Min.	Max.	Avg.	Min.	Max.	Avg.
Summer	0.05	0.11	0.07	0.006	0.019	0.010
Rainy	0.06	0.13	0.09	0.008	0.024	0.015
Autumn	0.02	0.15	0.12	0.005	0.029	0.016
Winter	0.11	0.30	0.17	0.009	0.039	0.021

Table 3. Values of radon-thoron progenies annul exposure, lifetime fatality risk factor, annual effective dose and inhalation dose in dwellings.

Values	**Annual exposure (Rn) (WLM)**	**Annual exposure (Tn) WLM**	**Annual exposure (Rn +Tn) (WLM)**	**Life time fatality risk factor ($\times10^{-4}$)**	**Annual effective dose (mSv/y)**	**Inhalation dose (mSv/y)**
Minimum	0.09	0.011	0.095	0.31	0.41	0.75
Maximum	0.17	0.025	0.181	0.54	0.70	1.61
Average	0.12	0.020	0.130	0.40	0.51	1.15

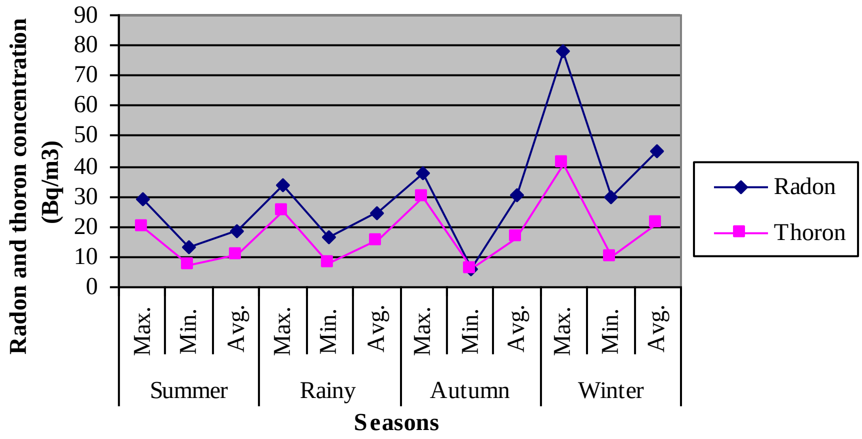

Figure 2. Seasonal variation of radon and thoron concentration in different season.

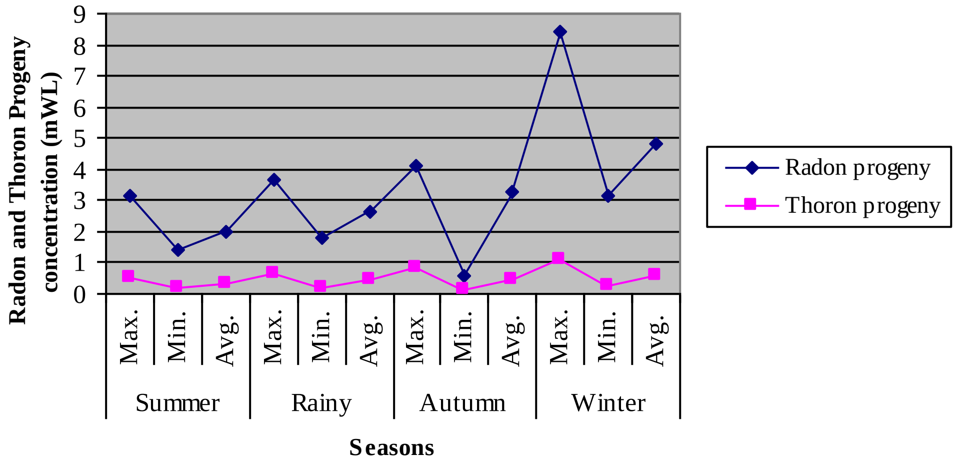

Figure 3. Seasonal variation of radon-thoron progeny concentration in different season.

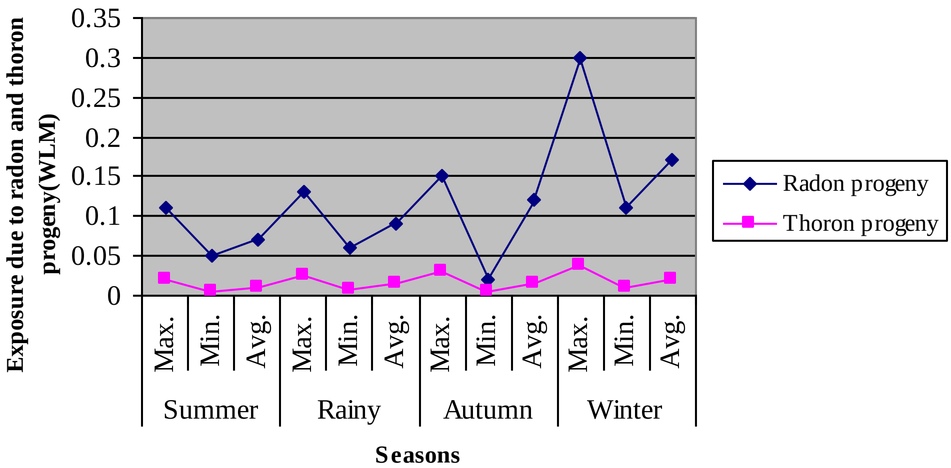

Figure 4. Seasonal variation of annual exposure due to radon-thoron progeny in different season.

IV. Conclusion

The results of indoor radon, thoron, radon progeny and thoron progeny concentration measured in the dwellings of Rampur District, where observations have been taken in different seasons of a calendar year are reported in the table1, where as the annual exposure due to radon progeny and thoron progeny, life time fatality risk factor, inhalation dose and annual effective dose are given in tables 2&3.The results shows quite higher radon and thoron levels in winter season as compared to the other season, thus clearly indicating the seasonal variations in the radon and thoron levels. This maximum concentration is essentially by the intense temperature inversion, which generally occurs in winter season when the wind velocity is low. The maximum concentration in winter is also the result of decreased ventilation because in this season the houses are closed for a long time and radon accumulated inside the room. The concentration of radon, thoron and their progeny levels in study area were observed below the recommended action level (200Bq/m^3) set by the various organizations (ICRP, 1993). It is observed that at all places in the study area, the annual inhalation dose and annual effective dose is below the action level 3-10 mSv/y has been recommended by ICRP (ICRP, 1993).The resulting doses were found to be well below internationally recommended action levels and are within the safe limit from the radiation protection point of view. Although the results obtained from the study area do not show major concern but the recorded values will play an important role in all comparative studies proposed in forth coming time and in estimating total radiation dose for habitants of Rampur District.

V. Acknowledgment

I would like to thank the residents living in the selected houses who willingly helped in the placement of the detectors in their homes.

References

[1] ICRP, 1993. International Commission on Radiological Protection. "*Protection against radon-222 at home and at work*", ICRP Publication 65, Annals of the ICRP 23(2), (Pergamon Press, Oxford).

[2] ICRP, 1981. *International Commission on Radiological Protection, Limits for inhaled radionuclides by workers*, ICRP publication 32, (Pergamon Press, Oxford).

[3] Jonassen, N., 1975. *A device for the determination of low natural ^{222}Ra and ^{222}Ra concentration*, Health Phys., 29,216-20.

[4] Martz, D. E., Rood, A. S., George, J. L., Pearson, M. D., Langner Jr. H., 1991. *Year to year to year variations in annual average indoor radon concentrations*. Health Phys. 61, 413.

[5] Mayya,Y.S, Eappan, K.P and Nambi, K. S. V.,1998. "*Methodology for mixed field inhalation dosimetry in monazite areas using a twin-cup dosimeter with three track detectors*", Radiation Protection and Dosimetry, 77, 177- 184.

[6] Miles, J.C.H., 1997. *Calibration and standardization of etched track detectors In Radon measurements by etched track detectors, applications in radiation protection*, earth Sciences and the Environment (Eds, Durrani, S.A., and IIic, R), World Scientific, Singapore, 143-176.

[7] Nazaroff, W.W., Doyle, S.M., 1985. *Radon entry in the houses having crawl space*. Health Phys. 48, 265.

[8] Ramola, R.C., Singh M., Singh S., and Virk H.S., 1987. Ind. J. Pure Appl. Phy. 25,127-129.

[9] Ramola, R.C., Negi, M.S. & Choubey, V.M., 2005. Radon, *thoron and their progeny concentrations in dwelling of Kumaun Himalaya- survey and outcomes*. J. Envir. Radioactivity, 79 (1), 85-92.

[10] Ramola, R.C., Rawat, R.B.S., Kandari, M.S., Ramachandran, T.V., & Choubey, V.M., 1998. *A study of seasonal variation of radon levels in different types of houses*. Jour. Environ. Radioactivity. 39 (1), 1-7.

[11] Ramola, R.C., Negi, M.S. & Choubey, V.M., 2005.Radon, *thoron and their progeny concentrations in dwelling of Kumaun Himalaya- survey and outcomes*. J. Envir. Radioactivity, 79 (1), 85-92.

[12] Ramola, R.C. Rawat, R.B.S., Kandari, M.S.,Ramachandran, T.V., & Choubey, V.M.,1997. *A study of seasonal variation of radon levels in different types of houses*. Jour. Environ. Radioactivity.39 (1), 1-7.

[13] Ramola, R.C., Rawat, R.B.S., Kandari, M.S., Ramachandran, T.V., Eappen, K.P. and Subba Ramu, M.C., 1996. *Calibration of LR-115 Plastic track detector for environmental radon measurements*. Indoor Built Environ. 5, 364-366.

[14] Ramola, R.C., Kandari, M. S., Negi, M. S., Choubey, V. M., 2000. J. Health Phys. 35,211-216.

[15] Ramola,R.C., Singh M., Singh S. and Virk H.S., 1992., J. Environ. Radioactivity.

[16] Ramachandran,T.V.,1998. Proc. of 11th *National Symposium on Solid State Nuclear Track Detectors*, Amritsar, pp. 50-68.

[17] Srivastava, D.S., Singh, P., Rana, N.P.S., Naqvi, A.H., Azam, A., Ramachandran, T.V. and Subba Ramu, M.C., 1995. *Calibration Factor for LR-115 Type II Track Detectors for Environmental Radon Measurements*. Nucl. Geophys. 9, 487-495.

[18] Subba RamuM.C., Muraleedharan T.V.and Shaikh A.N., 1998. Methods and

Measurements of Indoor Levels of Rn^{222} and its Daughters, BARC Rep. No. 1390.

[19] UNSCEAR, 1993. *Sources and effects of ionizing radiation. United Nations Scientific Committee on Effects of Atomic Radiation*. Report to General Assembly with annexes. United Nations sales Publications E.94.IX.2. United Nations New York.

[20] UNSCEAR, 2000. *United Nations Scientific Committee on the Effect of Atomic Radiation, 'Sources and Effects of Ionizing Radiation"*, Report to the General Assembly-UN, New York, 2000.

[21] Ward,W.J., Fleischer, R.L. and Mogro-Campero, A.,1997. *Barrier techniques for separate measurement of radon isotopes*. Rev. Sci. Instrum. 48, 1440-1441.