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Research Article

MEASUREMENTS OF ANNUAL EXPOSURE AND INHALATION DOSE DUE TO RADON AND ITS PROGENY IN THE DWELLINGS OF HARDOI DISTRICT (U.P.) BY USING SOLID STATE NUCLEAR TRACK DETECTOR (SSNTD)

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ABSTRACT
In the present study annual exposure and inhalation dose due to radon and its progeny were measured in some selected dwellings of Hardoi District (U.P.) by using solid state nuclear track detector (LR 115 Type-II Plastic track detector). The measurement was repeated on a time integrated four quarterly cycles to cover all the four seasons (summer, rainy, autumn & winter) of the calendar year. The value of annual exposure from radon progeny in the dwellings was found to vary from 0.046 WLM to 0.0.148 WLM with an average value of 0.097 WLM in summer season, 0.054 WLM to 0.130 WLM with an average value of 0.092 WLM in rainy season, 0.018 WLM to 0.156 WLM with an average value of 0.087 WLM in autumn season and 0.113 WLM to 0.292 WLM with an average value of 0.203 WLM in winter season where as the inhalation dose due to radon progeny was found to vary from 0.178 mSv/y to 0.57 mSv/y with an average value of 0.376 mSv/y in summer season, 0.209 mSv/y to 0.504 mSv/y with an average value of 0.356 mSv/y in rainy season, 0.069 mSv/y to 0.605 mSv/y with an average value of 0.337 mSv/y in autumn season and 0.438 mSv/y to 1.132 mSv/y with an average value of 0.787 mSv/y in winter season. The results shows higher value of annual exposure and inhalation dose in winter season as compared to the other season. At all the places the annual exposure and inhalation dose was found below to the action level 3-10 mSv/y as recommended by the International Commission on Radiation Protection (ICRP). Therefore, it is concluded that the study area is quite safe from radiation protection point of view.

Keywords: *Annual Exposure, Inhalation Dose, Radon, SSNTD, Progeny*

INTRODUCTION
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. Various researchers have reported that exposure to high levels of environmental smoke at the workplace and in other public sector indoor settings are important risk factors for lung cancer risk in workers (Kreuzer *et al.*, 2000). 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. Radon is well established human carcinogen for which extensive data are available extending into the range of general population exposure. 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 their subsequent deposition along the walls of various airways of the bronchial tree, provides the main pathway for radiation exposure to the lungs. Indoor radon and its decay products are assumed to be health hazardous for human. About 90% of average radiation dose received by human from natural sources and about 50% is due to inhalation of radon and its progeny present in the dwellings. Studies from different parts of the world show that the well-planned and systematic measurements of indoor radon concentrations for all seasons during a calendar year are necessary to calculate the actual dose due to exposure to indoor radon. The activity concentrations of indoor radon 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 (Ramola *et al.*, 1998, 2000, Subba Ramu *et al.*, 1998). To estimates the annual average equivalent dose, a number of indoor radon surveys have been carried out around the world (UNSCEAR, 1993). The aim of present work was to measure the indoor radon and their progeny concentration and then to calculate the inhalation dose, annual exposure due to radon and its progeny.

Study Area

The measurements annual exposure and inhalation dose due to indoor radon and their progeny were made in houses of Hardoi District of Uttar Pradesh. 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. The houses in study area are well, as well as poorly ventilated. Buildings are constructed of concrete, cement, bricks and blocks. Some houses, having glass doors and glass windows are also included in study.

MATERIALS AND METHODS

Methodology

For the measurement of indoor radon and their progeny concentration, twin cup radon dosimeter was used in the present study. Small pieces of detector film of size 2.5 cm x 2.5 cm. will be fixed in a twin cup radon dosimeter having three different mode holders' namely bare mode, filter mode and membrane mode. The exposure of the detector film 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 sandwiched between two glass fiber filter papers and is called membrane cup. The radon-thoron mixed field dosimeter system is shown in figure 1.

The detector 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 detector film exposed in the bare mode registers alpha tracks contributed by the concentrations of both gases and their alpha emitting progeny.

The dosimeters fitted with LR-115 plastic track detectors are suspended inside the selected houses of study area at a height of about two meters from the ground floor. At the end of the exposure time (usually about 90 days), the dosimeters are retrieved and all the three detector films 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. When alpha particles strikes on LR-115 film it creates narrow trails called tracks. The tracks produced by alpha particles in the film were counted by 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. The measured track densities for indoor radon is converted into Bqm^{-3} by using the formula,

$C = \rho / k t$

Where, C is the indoor radon concentration, ρ is the track density, k is the calibration factor (3.12×10^{-2} tracks cm^{-2} d^{-1}=1 Bqm^{-3}) and t is the exposure time.

The radon progeny concentration i.e. potential alpha energy concentration was calculated in milli working levels (mWL) by using the formula

$C\ (Bqm^{-3}) = PAEC\ (mWL) \times 3700/F$

Where, F is the equilibrium factor having value is 0.4 for radon (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). The annual exposure have been calculated through radon progeny by using the conversion factor 1 WLM= 36×WL.

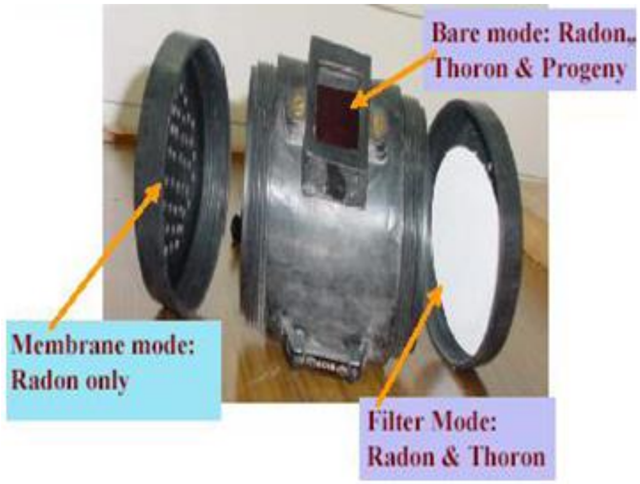

Figure 1: Radon-Thoron Mixed Field Dosimeter

RESULTS AND DISCUSSION

Observed values of radon and their progeny concentration from different location in a four different seasons of a calendar year are reported in a given table 1. From the observation it was found that in summer season the radon concentration varied from 12 Bq/m^3 to 38 Bq/m^3 with an average of 25.06 Bq/m^3. During rainy season the radon concentration was found to vary 13.87 Bq/m^3 to33.57 Bq/m^3 with an average of 23.68 Bq/m^3.

During autumn season the radon concentration was found to vary from 4.62 Bq/m^3 to 40.23 Bq/m^3 with an average of 22.47 Bq/m^3. During winter the radon concentration was found to vary 29.23 Bq/m^3 to75.11 Bq/m^3 with an average of 52.17 Bq/m^3.

The value of annual exposure from radon progeny in the dwellings was found to vary from 0.046 WLM to 0.0.148 WLM with an average value of 0.097 WLM in summer season, 0.054 WLM to 0.130 WLM with an average value of 0.092WLM in rainy season, 0.018 WLM to 0.156 WLM with an average value of 0.087 WLM in autumn season and 0.113 WLM to 0.292 WLM with an average value of 0.203 WLM in winter season.

The inhalation dose due to radon progeny was found to vary from 0.178 mSv/y to 0.57 mSv/y with an average value of 0.376 mSv/y in summer season, 0.209 mSv/y to 0.504 mSv/y with an average value of 0.356 mSv/y in rainy season, 0.069 mSv/y to 0.605 mSv/y with an average value of 0.337 mSv/y in autumn season and 0.438 mSv/y to 1.132 mSv/y with an average value of 0.787 mSv/y in winter season. The results shows higher value of annual exposure and inhalation dose in winter season as compared to the other season.

At all the places the annual exposure and inhalation dose was found below to the action level 3-10 mSv/y as recommended by the International Commission on Radiation Protection (ICRP).

Therefore, it is concluded that the study area is quite safe from radiation protection point of view. The variation of annual exposure and inhalation dose due to radon and its progeny in different season are shown in figures 2 & 3.

Table 1: Observed Values of Radon and their Progeny Concentration from Different Location

Season	Radon Concentration (Bq/m^3)			Potential Alpha Energy Concentration (mWL)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Summer	12	38	25.06	1.30	4.12	2.71
Rainy	13.87	33.57	23.68	1.50	3.63	2.56
Autumn	4.62	40.23	22.47	0.50	4.35	2.43
Winter	29.23	75.11	52.17	3.16	8.12	5.64

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Table 2: Values of Annual Exposure and Inhalation Dose in the Dwellings

Season	Annual Exposure (WLM)			Inhalation Dose (mSv/y)		
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Summer	0.04	0.15	0.10	0.19	0.57	0.38
Rainy	0.05	0.13	0.09	0.21	0.50	0.35
Autumn	0.02	0.16	0.08	0.07	0.61	0.36
Winter	0.11	0.29	0.20	0.44	1.13	0.79

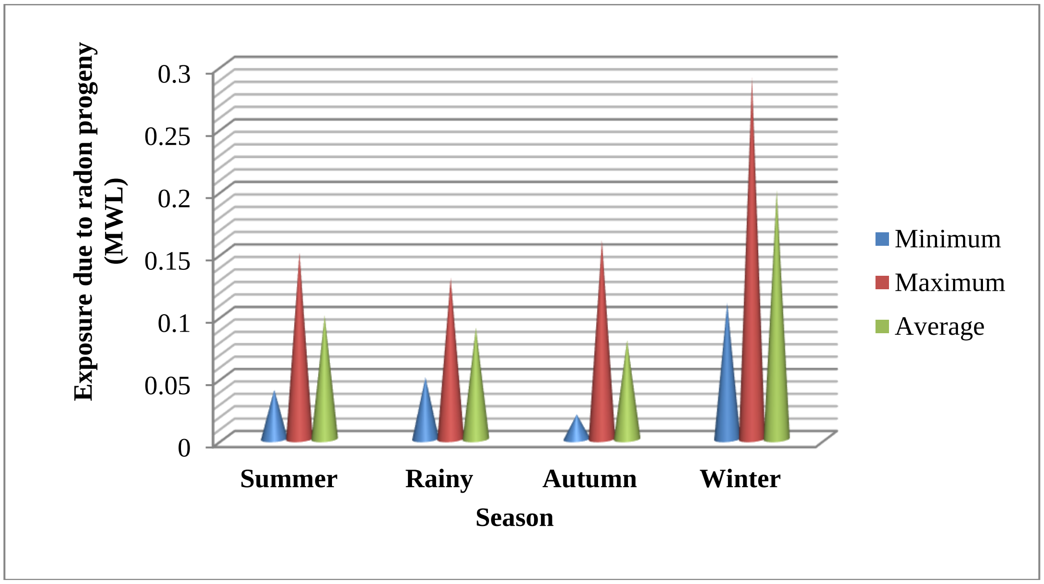

Figure 2: Variation of Annual Exposure due to Radon Progeny

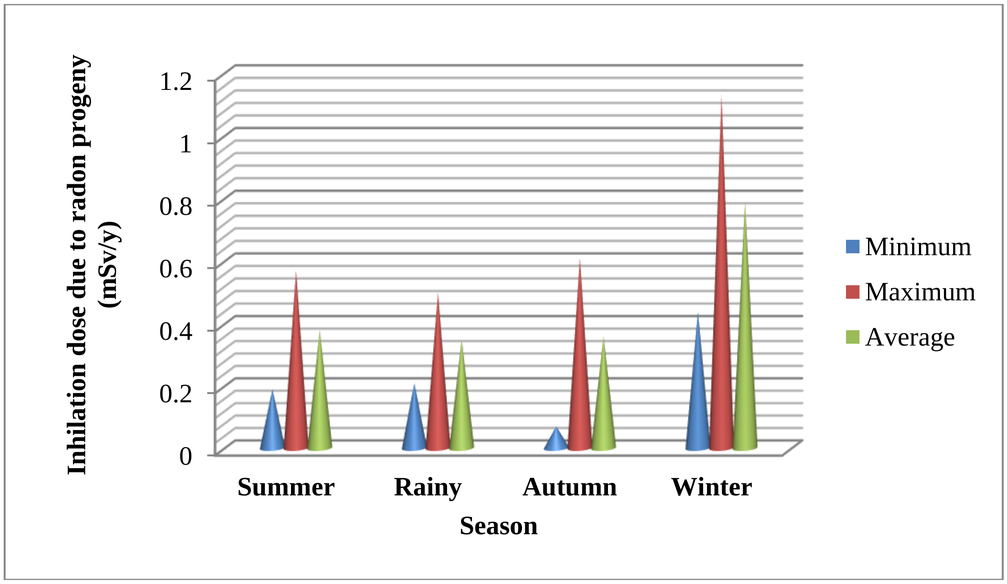

Figure 3: Variation of Inhalation Dose due to Radon Progeny

Conclusion

Measured values of indoor radon & their progeny concentration, annual exposure and inhalation dose from different location in the study area are reported in the table 1 & 2 respectively. The results shows quite higher radon levels in winter season as compared to the other season. This is due to fact that maximum concentration is essentially by the intense temperature inversion which generally occurs in winter season when the wind velocity is low. Also the ventilation becomes poor in winter due to lower exchange rate of air as the windows are kept closed. The concentration of radon and their progeny levels in the study area were observed below the recommended action level (200Bq/m^3) set by the various organizations (ICRP, 1993). The dose level i.e. annual exposure and inhalation dose at all places in the study area were observed below the action level 3-10 mSv/y as recommended by 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 Hardoi District.

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