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RESEARCH ARTICLE

Measurement of Radon Concentration, Annual Effective Dose and Annual Equivalent Dose to the Lungs in the Indoor Environment by Using SSNTD Technique

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ABSTRACT

The measurement of radon concentration, annual effective dose and annual equivalent dose has been carried out in the dwellings of Hardoi Disrict of Uttar Pradesh by using LR-115 Type II Solid State Nuclear Track Detector (SSNTD) technique. The radon concentration, annual effective dose and annual equivalent dose to the lung in the study area was found to vary from 20 Bq/m³ to 80 Bq/m³ with an average value of 54.13Bq/m³, 0.50 mSv/y to 2.02 mSv/y with an average value of 1.36Sv/y and 0.16 Sv/y to 0.64 Sv/y with an average value of 0.43Sv/y. The results of the study indicate that radon concentration, annual effective dose rate and annual equivalent dose to the lung was found bellow the recommended ICRP value (200Bq/m³ and 3-10 mSv/y) and does not pose any serious threat to the occupants. The indoor radon concentration has been found to vary considerably with the ventilation condition, construction of building materials, and volume of the room.

Key words: *Radon, Thoron, annual effective dose, annual equivalent dose and SSNTD*

INTRODUCTION

Radon (Rn) is a naturally occurring radioactive noble gas which exists in several isotopic forms. Only two of these isotopes occur in significant concentration in the general environment: radon-222 (usually referred to as "radon"), a member of the radioactive decay chain of uranium-238, and radon-220 (often referred to as "thoron"), a member of the decay chain of thorium-232. Radon is the first and only gaseous and inert element of the radioactive chains, so that it can easily leave the place of production (soil, rock and building material) and enter the indoor air. The contribution made by thoron to the human exposures in indoor environments is usually small compared with that due to radon, due to the much shorter half-life (55 seconds vs. 3.82 days), and it will only occasionally be referred to here. The contribution of various natural sources of radiation to the average annual effective dose is shown in figure 1. Natural radiation has always been part of the human environment. Its main components are cosmic and cosmogenic radiation, terrestrial gamma radiation from natural radionuclides in rocks and soil, and natural radioactive substances in our diet and in the air we breathe. Until the end of the 1970s the doses received by the vast majority of the general population from natural radiation were considered to be "background" phenomena of little significance, and the average annual dose was estimated to be about 1 mSv. The radioisotope Rn-222, produced from the decay of U-238, is the main source (approximately 55%) of internal radiation exposure to human life [1]. Worldwide average annual effective dose from ionizing radiation from natural sources is estimated to be 2.4 mSv of which about 1.0 mSv is due to radon exposure [2]. The measurement of radon in man's environment is of interest because of its alpha emitting nature. A certain fraction of the radon escapes into the air where, in the outdoors, it is quickly diluted and is of no further concern. However, in confined spaces such as homes and office buildings, radon can accumulate to harmful levels. Many environmental pollutants are classified as cancer-causing solely on the basis of laboratory studies using either animals or cell cultures. In the case of radon, there is direct evidence from human studies of a link between exposure to radon and lung cancer. For this reason radon has been classified by the International Agency for Research on Cancer, a branch of the World Health Organization, as a Group 1 carcinogen. This places radon in the same group of carcinogens as asbestos and tobacco smoke. Most of our time is spent indoors; therefore, the measurement and evaluation of radon concentrations in buildings are important [3 and 4].

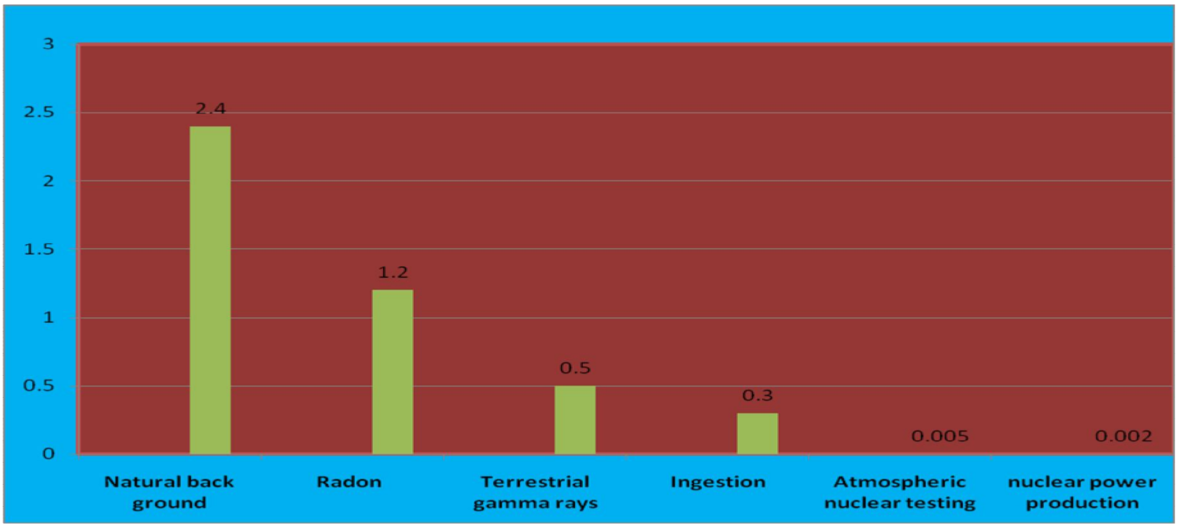

Fig.1: Contribution of various natural sources of radiation to the average annual effective dose

STUDY AREA

The measurement of radon concentration, annual effective dose and annual equivalent dose to the lungs were made in the dwellings of Hardoi district of Uttar Pradesh. Most of the dwellings in the Hardoi city are constructed of cement and brick where as in the surrounding villages the walls and floors are made of local sandstone and rock with a mud paste. The dwellings in the villages have poor ventilation condition, commonly with one door and one small window and some without ventilation.

EXPERIMENTAL TECHNIQUE

Solid State Nuclear Track Detectors (SSNTDs) have been used for the measurements of radon concentration, annual effective dose and annual equivalent dose to the lung. Solid State Nuclear Track Detectors (SSNTDs) are insulating solids both naturally occurring and man-made [5]. In this present work, the technique of using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the study of indoor radon in dwellings of the study area. The radon (^{222}Rn) concentration is calculated from the track density. The annual equivalent dose rate to the lung received by the population is calculated based on guidelines given by the International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the Effects of Atomic Radiation [6]. The main objective of this work was to assess the indoor radon concentration, the annual effective dose rate, the annual dose equivalent rate to the lung and the associated level of risk to the populace.

The small Pieces of detector film of 2.5 cm x 2.5 cm. will be fixed in a twin cup radon dosimeter (Fig. 2) having three different mode holders' namely bare mode, filter mode and membrane mode. The bare mode detector registers track due to radon, thoron gases and their progeny concentrations while the filter made detector records tracks due to the radon and thoron gases, membrane made records tracks only by radon gas. Radon-Thoron mixed field dosimeter system is shown in the figure 2. The dosimeters fitted with LR-115 plastic track detectors are suspended inside the selected houses in field area at a height of about 150 cm to 200 cm from the ground floor. When alpha particles strikes on LR-115 film it creates narrow trails called Tracks. The detectors were exposed for a period of three months and, after retrieval, were etched for two hours in 2.5 N NaOH solution maintained at 60˚C in constant temperature bath and scanned in the laboratory for the track density using spark counter. The measured track densities for indoor radon, is then converted into radon activity concentrations (Bqm^{-3}) by applying the calibration factor for LR-115 type II bare detector.

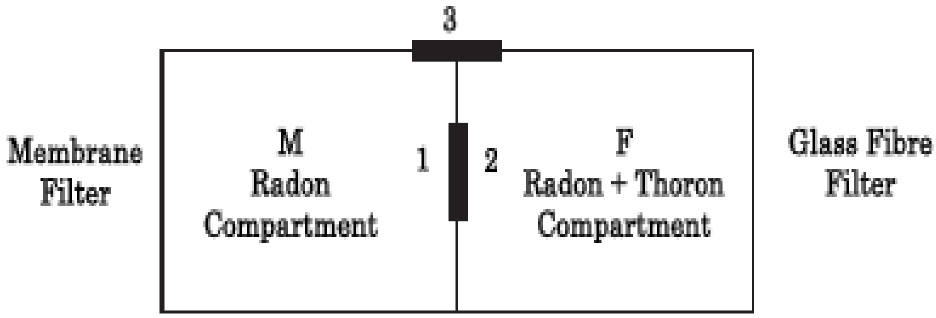

Fig. 2: Schematic diagram of twin Cup of radon-Thoron dosimeter

The track density was calculated using the equation below:

Track density (D) = Average number of sparks/Area of electrode

Concentration of indoor radon gas in Bq/m^3 was calculated using the formula below:

$$\text{Concentration } (kBq/m^3) = \rho - \rho_B / \varepsilon T \text{ (h)}$$

where,
ρ =Track density
ρ_B = Background track density
ε = Calibration factor ($Tracks.m^3 / cm^2 kBq.h$) of the LR-115 (Type II)
T (h) = Exposure time in hours.

In order to estimate the annual effective dose rate received by the population, one has to take into account the conversion co-efficient from the absorbed dose and the indoor occupancy factor. According to the UNSCEAR (2000) report the committee proposed 9.0×10^{-6} mSv/h per Bq/m^3 to be used as a conversion factor, 0.4 for the equilibrium factor of Rn-222 indoors and 0.8 for the indoor occupancy factor. At a certain radon concentration C_{Rn} in Bq/m^3, the annual absorbed dose, D_{Rn} is usually expressed in the unit of mSv from the following relation below:

$$D_{Rn} (mSv/y) = C_{Rn}. D. H. F.T$$

where,
C_{Rn} is the measured Rn-222 concentration (in Bq/m^3),
F is the R n-222 equilibrium factor indoors (0.4),
T is the indoor occupancy time 24 h ×365 = 8760 h/y
H is the indoor occupancy factor (0.8), and
D is the dose conversion factor (9.0×10^{-6} mSv/h per Bq/m^3).

Now to calculate the annual equivalent dose and effective dose, one has to apply a tissue and radiation weighting factors according to ICRP [6]. The equivalent dose is the radiation- weighted absorbed dose. The radiation weighting (W_R) factor for alpha particles is 20 as recommended by ICRP [6]. With the effective dose, a tissue weighting (W_T) factor is applied. According to ICRP, the tissue weighting factor for lung is 0.12. The annual effective dose is then calculated according to the equation below:

$$H_E\ (mSv/y) = D_{Rn}\,.W_R.W_T$$

where,
D_{Rn} = Annual Absorbed dose
W_R = Radiation Weighting Factor for Alpha Particles, 20
W_T = Tissue Weighting Factor for the Lung 0.12

It is, however, apparent that the time spent by individuals in the home varies widely globally. The occupancy factor of 0.8 (1) over estimates the excess lung cancer risk in the tropical regions but may be valid for the inhabitants of the cold climate zone [7, 8 and 9]. In the tropical regions, people spend most of their time in open-air and only go indoors to sleep at night. In this present Study, the occupancy factor that was used for the annual absorbed dose calculation will be 40% (0.4).The indoor occupancy factor used was calculated, based on the fact that dwellers spend only about 9hours indoors out of the 24 h in a day. In the case of the annual equivalent dose to the lungs, the radon content of the lung air has to be taken into account, which results in the equation below according to UNSCEAR, 2000[2]:

$$H_{lungs}\ (Sv) = 8 \times 10^{-10} \times C_{Rn}\ (Bq/m^3)$$

RESULTS AND DISCUSSION

The observed values of radon concentration, annual effective dose rate and annual equivalent dose to the lung are given in the table 1. The present study shows that the indoor radon concentration, annual effective dose and annual equivalent dose to the lung was found to vary from 20 Bq/m³ to 80 Bq/m³ with an average o f 54.13 Bq/m³, 0.50 mSv/y to 2.02 mSv/y with an average of 1.36 mSv/y and 0.16 Sv/y to 0.64Sv/y with an average value of 0.43Sv/y respectively.). The lowest value of radon concentration was found to be 20 Bq/m³, where as the highest concentration was found to be 80 Bq/m³. The highest value of radon concentration (80 Bq/m³) was observed at location RMAP (80 Bq/m³) and an annual effective dose rate of 2.02 mSv/y. The high radon concentration level at location RMAP is due to poor ventilation, lifestyle and the accumulation of dust in the room due to the closeness of the dwelling to the road side which are usually considered as important sources of radon in buildings.

Table 1: Observed values of radon concentration, annual effective dose rate and annual equivalent dose to the lung

S. No.	Locations	Radon concentration (Bq/m³)	Annual effective dose (mSv/y)	Annual equivalent dose to the lung(Sv/y)
1	RMAP	80	2.02	0.64
2	RMHN	45	1.13	0.36
3	RMPW	65	1.63	0.52
4	RMKK	60	1.51	0.48
5	RMGT	45	1.14	0.36
6	RMTC	50	1.26	0.40
7	RMZI	52	1.31	0.42
8	RMDR	76	1.91	0.61
9	RMEV	53	1.34	0.42
10	RMSE	56	1.41	0.45
11	RMBT	45	1.12	0.36
12	RMPL	20	0.50	0.16
13	RMBS	28	0.70	0.22
14	RMZS	67	1.69	0.52
15	RMKB	70	1.77	0.56
Average		**54.13**	**1.36**	**0.43**

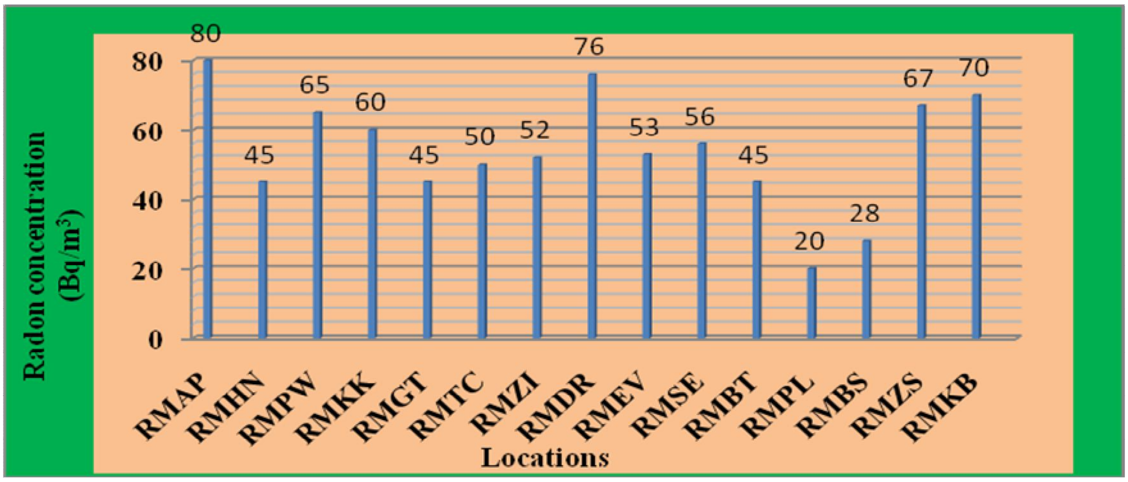

Fig. 3: Average radon concentration at different locations

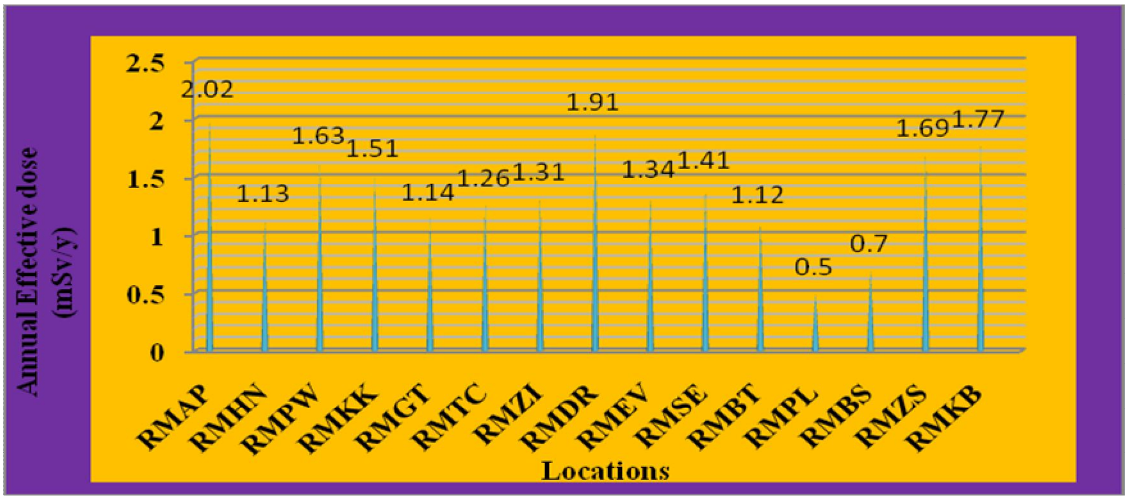

Fig. 4: Annual average effective dose rate at different locations

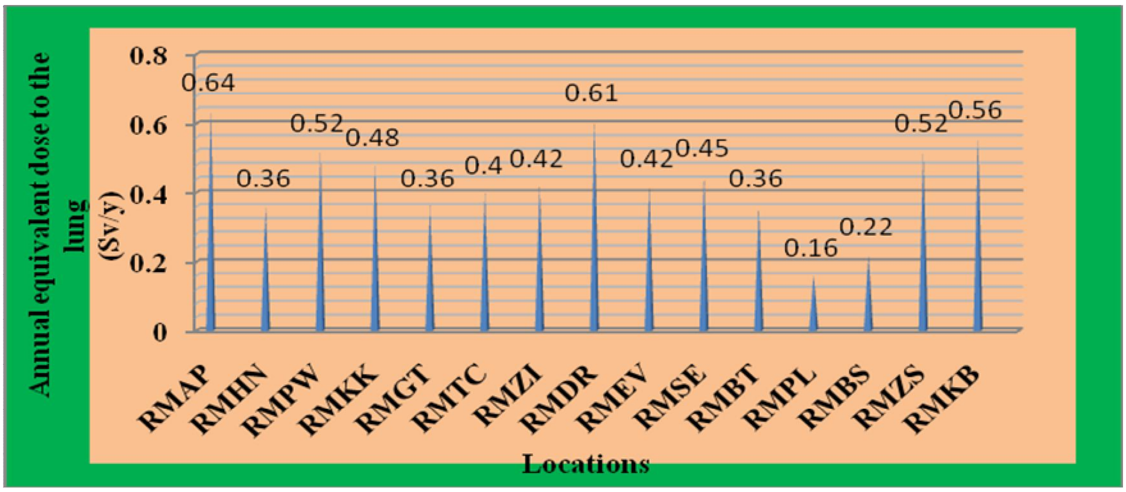

Fig. 5: Annual average equivalent dose rate to the lungs at different locations

The lowest value of radon concentration (20 Bq/m^3) was found at location RMPL and an annual effective dose of 0.50 mSv/y which is probably due to adequate ventilation. The annual equivalent dose to the lung was found to vary 0.16 Sv/y to 0.64 Sv/y with an average value of 0.43Sv/y .The results of the study indicate that radon concentration, annual effective dose rate and annual equivalent dose to the lung was found bellow the recommended ICRP value (200Bq/m^3 and 3-10 mSv/y) and does not pose any serious threat to the occupants. Consequently, the relative lung cancer risk from radon exposure is low in these buildings and they can be considered safe when the hazardous health effects of radon are concerned [10]. The variation of radon concentration, annual equivalent dose and annual equivalent dose to the lung at different locations are represented graphically in Fig. 2, 3 and 4 respectively.

CONCLUSION

The results of the present research led to the conclusion that the radon concentration, annual effective dose and annual equivalent dose to the lung in the study area was found to vary from 20 Bq/m^3 to 80 Bq/m^3 with an average value of 53.13Bq/m^3, 0.50 mSv/y to 2.02 mSv/y with an average value of 1.36Sv/y and 0.16 Sv/y to 0.64 Sv/y with an average value of 0.43Sv/y. The results of the study indicate that radon concentration, annual effective dose rate and annual equivalent dose to the lung was found bellow the recommended ICRP value (200Bq/m^3 and 3-10 mSv/y) and does not pose any serious threat to the occupants. Consequently, the relative lung cancer risk from radon exposure is low in these buildings and they can be considered safe when the hazardous health effects of radon are concerned.

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