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Radiation dose in the indoor atmosphere due to radon and thoron

MSA Khan
Department of physics, Gandhi Faiz-a-Aam College, Shahjahanpur-(U.P.)

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Abstract
Radio nuclides ^{222}Rn and ^{220}Rn, from the uranium and thorium decay chains are noble gases produced by the decay of their immediate respective nuclides ^{226}Ra and ^{224}Ra present in the rocks, uranium ores and soils. These gases can leave the earth's crust by processes such as diffusion, advection, and enter in the atmosphere. ^{222}Rn and ^{220}Rn decay products are the radioactive isotopes of polonium, bismuth, lead and thallium. These daughter products, being the isotopes of heavy metals, get attached to the existing aerosol particles in the atmosphere. Radiation dose in the indoor atmosphere due to radon and thoron has been carried out in the dwelling of Rampur District (U.P.).The significant contribution to the total dose received by the population is subjected to the natural radiation due to the inhalation of ^{222}Rn, ^{220}Rn and their decay products. LR-115 Type II Solid State Nuclear Track Detector (SSNTD) technique was used for the measurements of the ^{222}Rn concentrations, annual effective dose rate and annual equivalent dose rate to the lung in the studied area. The mean annual effective dose rate and the mean annual equivalent dose rate to the lung in the studied area were found to be 1.36 mSv/y and 0.43Sv/y, respectively. The radon concentration was found varied from 20Bq/m^3 to 80 Bq/m^3 with an average value of 54.13 Bq/m^3 which is less than recommended ICRP value (148 Bq/m^3) and therefore 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.

1. Introduction

Radon is a naturally occurring odorless, colorless, tasteless inert gas which is imperceptible to our senses. It is produced continuously from the decay of naturally occurring radionuclide such as U-238, U-235 and Th-323.The radioisotope Rn-222, produced from the decay of U-238, is the main source (approximately 55%) of internal radiation exposure to human life (ICRP, 1993).Worldwide average annual effective dose from ionizing radiation from natural sources is estimated to be 2.4mSv of which about 1.0 mSv is due to radon exposure (UNSCEAR, 2000). 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 (Risica, 1998; Hamori et al., 2004). Worldwide measurements of radon activities in the indoor air of dwellings are continuously presented all over the world (Singh et al., 2002; Iyogi et al., 2003).The numerous measurements of the activity concentrations of radon in different countries along with epidemiological studies regarding the indoor radon and risk of lung cancer have been published in recent years (Field et al., 2000). The main natural sources of indoor radon are soil, building materials (sand, rocks, cement, etc.,), tap water, natural energy sources used for cooking like (gas, coal, etc.,) which contain traces of U-238, the topography of the area, house construction type, soil characteristics, ventilation rate, wind direction, atmospheric pressure and even the life style of people. 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.

2. Experimental Techniques

The Solid State Nuclear Track Detectors (SSNTDs) is an important tool in investigations concerning the presence of radon gas. Solid State Nuclear Track Detectors (SSNTDs) (Fleischer et al., 1975) are insulating solids both naturally occurring and man-made. In this present work, the technique of using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the study of indoor radon and thoron level in dwellings of the study area. The radon (^{222}Rn) and thoron (^{220}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 (UNSCEAR).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.

LR-115 type II detectors were cut into rectangles and placed in specially made envelopes (Fig. 1) from cardboards. The detectors were hanged in the various dwellings of the study area at a height of 2m from the ground level. The sensitive lower surface of the detector was freely exposed to the emergent radon/thoron so that it was capable of recording the alpha-particles resulting from the decay of radon/thoron in the room. After the 3 months exposure, the detectors were subjected to chemical etching in a 2.5N analytical grade sodium hydroxide solution at 60ºC, for 90 m in a constant temperature water bath to enlarge the latent tracks produced by alpha particles from the decay of radon. After the etching, the detectors were washed with running cold water, then with distilled water. After a few minutes of drying in air, the detectors were ready for track counting. The tracks were counted thrice for each detector and the average was calculated. The track densities were then converted into radon and thoron concentration by applying the calibration factor for LR-115 type II bare detector.
The track density was calculated using the equation:
Track density (D) = Average number of sparks/Area of electrode
Concentration of indoor radon gas in Bq/m^3 was calculated using the formula:

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

***Corresponding Author,**
E-mail address: salim_labphysics@rediffmail.com

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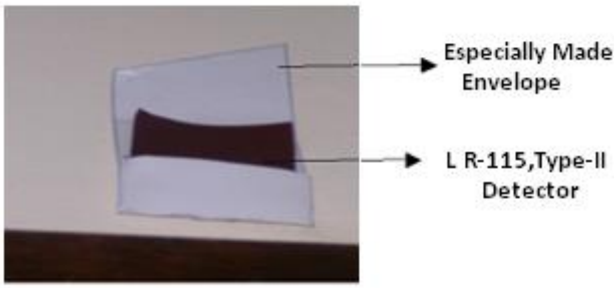
Where ρ is the track density, ρ_B is the background track density, ε is the calibration factor (Tracks.m^3 / cm^2 kBq.h) of the LR-115, Type II and T is the exposure time in hours.In order to estimate the annual effective dose rate received by the population, one has to take into account the conversion co-efficient from the absorbed



dose and the indoor occupancy factor. According to the UNSCEAR (2000) report, the committee proposed 9.0 x 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 ^{222}R n 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).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} is the annual absorbed dose,W_R is radiation weighting factor for alpha particles, (20), and W_T is the tissue weighting factor for the lung (0.12).The occupancy factor of 0.8 (ICRP, 1993, 1991) over estimates the excess lung cancer risk in the tropical regions but may be valid for the inhabitants of the cold climate zone. 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 9 hours 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:

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

3. Result 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 obtained varied from 20 Bq/m^3 to 80 Bq/m^3 with an average o f 54.13 Bq/m^3 which is within the recommended ICRP action level of 200 Bq/m^3 (ICRP, 1993).

The lowest value concentration was found to be 20 Bq/m^3, where as the highest concentration was found to be 80 Bq/m^3.The annual effective dose from the corresponding measured radon concentration in the different houses has been calculated which varies from 0.50 mSv/y to 2.02 mSv/y with an average of 1.36 mSv/y which is also within the recommended ICRP intervention level of (3-10) mSv/y (ICRP, 1993).The highest value of radon concentration (80 Bq/m^3) was observed at location RMAP (80 Bq/m^3) and an annual effective dose rate of 2.02 mSv/y. The high radon concentration level at location RMAP is due to poor

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

S. No.	Locations	Radon concentration (Bq/m^3)	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

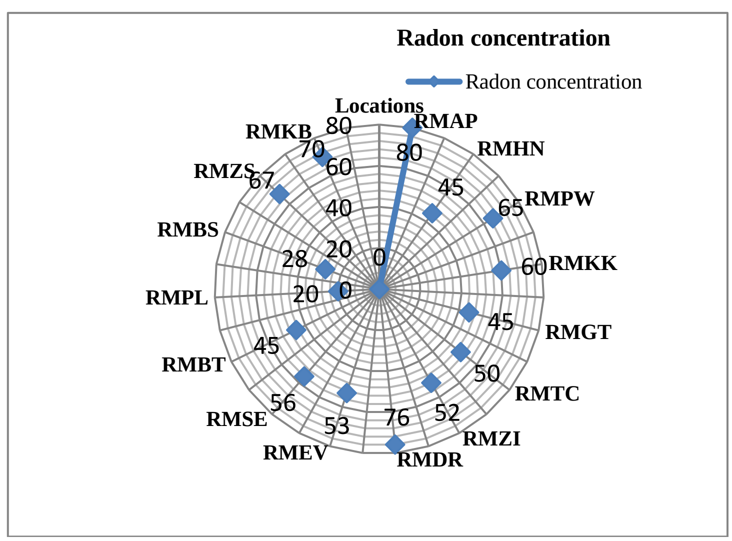


Fig. 2: Average radon concentration at different locations

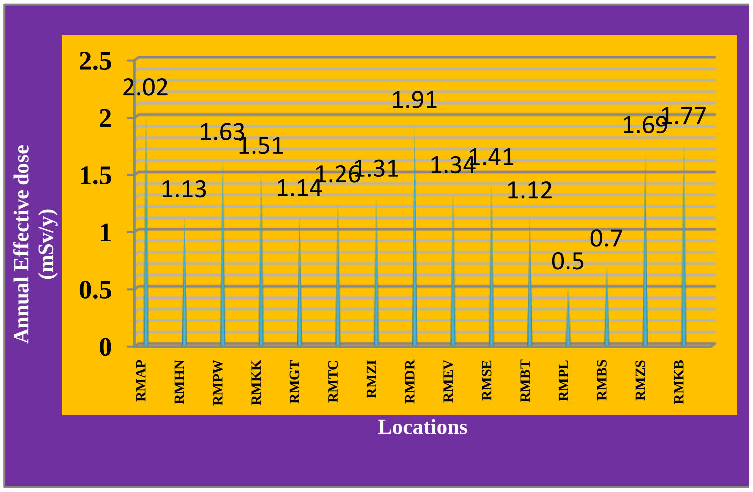


Fig. 3: Annual average effective dose rate at different locations

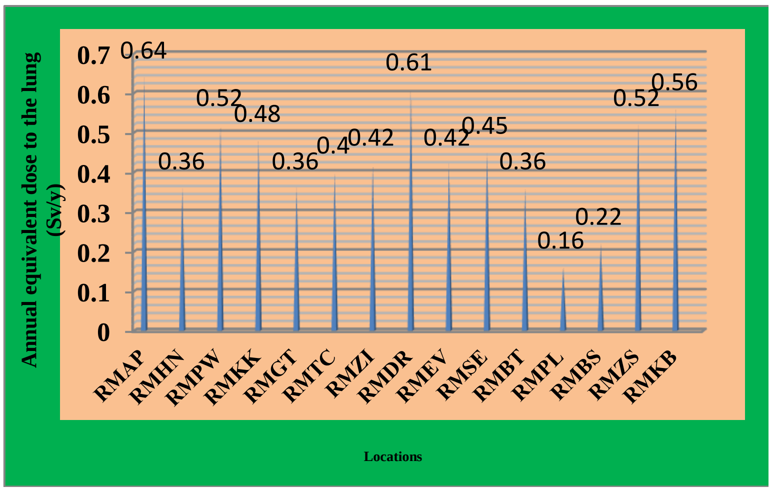


Fig. 3: Annual average equivalent dose rate to the lungs at different locations

ventilation, lifestyle and the accumulation of dust in the room due to the closeness of the house to the road side which are usually considered as important sources of radon in buildings. 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 of0.43Sv/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 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. 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.

4. Conclusions

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 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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