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Effect of ventilation conditions on the annual effective dose due to indoor radon concentration

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ABSTRACT

Radon and its progeny present in houses and others dwellings represents the most important contribution to dose from natural sources of radiations. The measurements of indoor radon are performed by using passive LR-115 nuclear track detectors calibrated at NIRS, Japan during the 4th International Intercomparison of Radon and Thoron Passive detectors. The values of indoor radon concentration vary from 54.26 Bqm^{-3} to 141.09 Bqm^{-3} with an average value of 97.68 Bqm^{-3}. However, the value of effective dose varies from 0.93 mSvy^{-1} to 2.41 mSvy^{-1} with an average value of 1.67 mSvy^{-1}. An attempt is made to estimate the effect of ventilation conditions on the annual effective dose due to indoor radon concentration. The dwellings were selected on the basis of different ventilation conditions. The result of the present study indicates that changes of ventilation rate have significant effects on indoor radon concentration. Ventilation rate is inversely proportional to indoor radon concentration. In general, all the results of indoor radon concentration are found to be well within the recommended action level (200–300Bqm^{-3}) by the International Commission of Radiation Protection (ICRP, 2009) but are on the higher side than the world average of 40 Bqm^{-3}. Also the values of effective dose levels are found to be lower than the average value of 2.4 mSvy^{-1} given by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000).

Keywords: Radon; Environment; SSNTDs; Effective dose; LR-115 etc.

INTRODUCTION

Radon (^{222}Rn) and thoron (^{220}Rn) are two main sources of natural radioactivity in the atmosphere out of which radon contributes more than half of all non-medical exposure to ionizing radiation dose received by general population [1]. The measurement of radon in man's environment is of interest because of its emitting nature of alpha particles. Due to its short half-life ($T_{1/2}$=3.82 s) it diffuses through soil and into the air. Inhalation of the ^{222}Rn's short-lived progeny is responsible of about half of the total effective dose received by humans from all natural sources of ionizing radiation [2]. Long-term exposure to elevated radon (^{222} Rn) concentrations has been linked to increased lung cancer risk. Recent case-control epidemiologic studies of residentially-exposed individuals use year-long measurements of contemporary radon concentrations as the "gold standard" to estimate exposures over past decades [3-8]. Radon levels indoors depend on the concentration of radon in the ground, details of construction of the house, and the way the house is heated and ventilated. The radon gas can enter the body via respiring, drinking and eating. The alpha particles emitted by radon gas and other radiations emitted by its daughter products increase the absorbed dose in respiratory and digestion systems. Radon exposure variability seems to be affected by several factors: soil temperature [9], soil permeability [10], moisture state [11], temperature differences between the interior and exterior of buildings [12], air pressure variations [13-15], materials used for building constructions and the degree of ventilation of closed environments [16], among the most important. The concentration of indoor radon also depends on the ventilation rate of the dwellings. It is important to note that a reduced ventilation rate helps enhance the concentration of radon and its progenies in the air. The track etch technique is recognized as the most reliable for the integrated and long–term measurement of indoor radon [17]. Most of our time is spent indoors; therefore, the measurement and evaluation of radon concentrations in buildings are important [18-19]. 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) are insulating solids both naturally occurring and man-made [20]. In India many research workers are engaged in the measurement of indoor radon levels in dwellings for health risk assessments and its control [21-24]. In this present work, the technique of using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the study of indoor radon level.

MATERIALS AND METHODS

Experimental method for radon detection and measurement are based on alpha-counting of radon and its daughters. Active and passive devices are available in the literature for this purpose. In the present investigations, the passive technique using the Solid State Nuclear Track Detectors (SSNTDs) which is the most reliable technique for the integrated and long-term monitoring of radon [25-27] has been utilized for the comparative study of the indoor radon level. LR-115 Type II SSNTDs which mainly detects the alpha particles having energy ranging from 1.7 to 4.8MeV were used for this study. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light [28] . The detector films of size 1.5×1.5 cm^2 were suspended for different time period in bare mode in the dwellings at a height of more than 2m above the ground level and about 1m below the ceilings and away from the walls so that the direct alpha particles from the building material of the dwellings would not reach the detector films. The detectors were removed and etched using 2.5N NaOH solution at 60°C for 90min. The tracks density was counted using an optical microscope at 400× magnification.

RESULTS AND DISCUSSION

The annual average radon concentration, average annual effective dose and average lifetime fatality risk for each of the locations have also been calculated as shown in Table 1.

Table 1:- Effect of ventilation condition on indoor radon concentration and annual effective dose

Sr. No	Detectors	Exposure time(h)	Condition	Radon concentration ($Bq\ m^{-3}$)	Life Time Fatality Risk X 10^{-4}	Average Effective Dose (mSv)	Annual exposure (WLM)
1	H1	50	Poorly ventilated	130.24	1.72	2.22	0.58
2	H2	100	Poorly ventilated	141.09	1.82	2.41	0.63
3	H3	50	Highly ventilated	97.68	1.29	1.67	0.43
4	H4	100	Highly ventilated	65.12	0.86	1.11	0.29
5	H5	50	Poorly ventilated	119.39	1.56	2.04	0.53
6	L1	50	Partially ventilated	75.97	1	1.3	0.34
7	L2	100	Partially ventilated	108.53	1.43	1.85	0.48
8	L3	50	Highly ventilated	54.26	0.72	0.93	0.24
9	L4	50	Partially ventilated	86.83	1.15	1.48	0.39

The values of indoor radon concentration vary from 54.26 Bqm^{-3} to 141.09 Bqm^{-3} with an average value of 97.68 Bqm^{-3}. The radon 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). For radon concentration calculations, track density is converted into working level concentration using 1WL=442 Tracks cm^{-2} day^{-1}. Also equilibrium factors (F) of value 0.4 for locations have been used. Radon concentration in Becquerel per cubic meters ($Bq\ m^{-3}$) is calculated using the formula [29-30] as given in equation (1):

$$\text{Radon concentration } (Bqm^{-3}) = (WL\ 3700) / F \qquad (1)$$

Calculations have been made using the conversion factors given elsewhere [30-31]. ICRP assumes 80% occupancy (7000 h/yr) indoors. However indoor radon concentration values are less than the lower limit of the range of the action level (200–300 $Bq\ m^{-3}$) recommended by the International Commission on Radiological Protection [32]. One working level month (WLM) corresponds to the exposure of an individual to radon progeny of 1WL concentration (2.08×10^{-2} mJ m^{-3}) for a duration of 170 h which results in 1 WLM equivalent to 3.54 mJ h m^{-3}. The conversion factors of 3×10^{-4} WLM^{-1} and 3.88 $mSvWLM^{-1}$ [30] are used for calculating the lifetime fatality risk and the annual effective dose, respectively. The dwellings under study are built, in general, using different materials, cement, sand, stones, bricks, iron structure, marble and concrete as the construction materials. Several of these materials are expected to contribute significantly to sources of indoor radon. Our assumptions for this study is that a room with a door but without a window would be poorly ventilated, that with one door and one window is partially ventilated and with more than two windows and a door is well ventilated. The annual effective inhalation dose from measured radon levels is calculated according to ICRP Publication, 1993[30]. The value of effective dose varies from 0.93 $mSvy^{-1}$ to 2.41 $mSvy^{-1}$ with an average value of 1.67 $mSvy^{-1}$. The high radon concentration level is due to poor ventilation, lifestyle and the accumulation of dust in the room due to the closeness of the house to the roadside which are usually considered as important sources of radon in buildings. Although all the values of the indoor radon concentration are within the ICRP action level and some of the values are higher than the new reference level (100 Bqm^{-3}) set by WHO [33]. But the average value is higher than the world average radon concentration of 40 Bq/m^3 [2]. This may be due to the difference in the concentration of radioactive elements, viz. uranium and radium in the soil and building materials of the study area, which has also been reported in studies of soil samples from similar geological conditions in Malwa region of Punjab [34-35]. The ventilation rate is shown to be an important factor in reducing indoor radon level, not only from the result of this study, but also from other research work [36]. As the outdoor radon level indicates the minimum indoor radon level that the premises can sustain, the critical ventilation rate shown in this study provides a preliminary guideline so that the minimum indoor radon level can be achieved if the ventilation rate is kept above the critical value. Future research work is being conducted to expand the database so that a more accurate critical ventilation rate can be defined.

CONCLUSION

Radon concentrations and annual effective dose are well below the recommended safe limit values. It is found that radon activity and radon effective dose rate depend upon many factors inside the dwellings. It has been found that the ventilation rate plays a very important role in controlling indoor radon concentration. Comparatively high values of radon concentration are reported in poorly ventilated houses as compared with the well ventilated houses.

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