



Original Research

Science Vision 16 (1)  
January-March  
ISSN (print) 0975-6175  
ISSN (online) 2229-6026

## Annual inhalation dose of indoor radon in dwellings in Aizawl City, Mizoram, India

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Received 18 January 2016 | Revised 2 February 2016 | Accepted 10 February 2016

### ABSTRACT

Radon gas is found in the environment, indoor and outdoor and its parent element being traced back to  $U^{238}$ . Study of indoor radon inhalation dose have been carried out in Aizawl City, Mizoram, India in 24 dwellings, which were specifically selected according to the site location of the dwellings. Solid-state nuclear track detectors (SSNTD) have been used to obtain the time integrated concentration levels of indoor radon. DRPS (direct radon progeny sensor), which selectively register the tracks due to alpha emissions from  $^{214}Po$  from the deposited atoms of  $^{222}Rn$  progeny species is used for estimating the equilibrium equivalent radon concentration (EERC). The equilibrium factor (F-factor) for radon is then calculated using the measured EERC and concentrations of radon. The equilibrium factor may be defined as ratio of the amount of progeny nucleus to that of a parent nucleus. Inhalation dose has been obtained from the measured F-factor and concentrations of indoor radon. The data obtained in the present work has been analyzed to obtain the significant inhalation dose of indoor radon. From these observations it has been found that the annual inhalation dose of indoor radon in the study area is 624.89  $\mu Sv/y$ , which is low in comparison to the global average.

**Key words:** DRPS; EERC; F-factor; Inhalation dose; Radon; SSNTD.

### INTRODUCTION

Radon and their progeny concentrations contribute most of the natural radiation dose to gen-

eral populations. This fact draws a considerable attention and hence, large scale and long-term measurement of radon concentrations has been going on. Radon present in indoor as well as outdoor air as they had been exhaled from soil and building materials. Radon levels in the indoor environment and environment of work

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places have been realized as a concern of public health in many countries and even in India. Consequently, studies related to monitoring of radon and the inhalation dose to the public living in that environment has been a keen interest.<sup>1</sup> Measurement of radon concentrations was done over the past fifty years in many countries, but with the improvement of experimental apparatus and technical formulation, the same is going on till today.

Radon is continually formed in soil and is released to air. Subsequent decay products are formed in the air. It is well-known that in radon problem, the progeny species and not the radon are primarily responsible for lung doses. Among the progenies, short lived nuclei viz.  $^{214}\text{Po}$  is focused due to its high contribution in deposition and emission of alpha particles inside the lung.<sup>2</sup>

Annual inhalation dose rate is the amount of radon inhaled per annum ( $\mu\text{Sv}/\text{yr}$ ) by individuals living in dwellings. Inhalation dose can be calculated using the obtained concentrations of the parent nuclei and the progenies. For this calculation, the equilibrium factor (F-factor) of radon is required. The equilibrium factor for radon was a globally assumed value and even the calculation of radon progenies were inferred using this value. With the advent of passive detection techniques using solid state nuclear track detectors (SSNTDs), direct progeny sensor (DPS) has been developed. Using DPS, direct experimental determination of F-factor of radon is possible.

In this report, we present the works on indoor radon concentration and inhalation dose of the same in the dwellings in Aizawl City, the state capital of Mizoram. As there is no man made sources of radiation present in these areas, like refinery, thermal power plant, geothermal springs, slate mines, industrial zones, etc., the main sources of radiation obtained from these studies is mainly due to natural radiation.

## MATERIALS AND METHODS

The concentrations of the parent nuclei and progenies are required to obtain the equilibrium factor as well as the inhalation dose. In measur-

ing indoor radon concentrations, solid state nuclear track detector (SSNTD) based pin-hole dosimeters have been used. The dosimeter system is a cylindrical plastic chamber in which LR-115 (Type-II) films are used as detectors. Radon gases are allowed to enter through a pin-hole, which is designed in size and thickness of cap so as to allow the entry of only radon gases and block other nuclei.<sup>3</sup> The concentrations of progeny were determined through EERC by using DRPS. DRPS detector system is based on selectively registering alpha tracks originating from the deposited progeny activity on LR-115 type solid-state nuclear track detectors. The radon progeny sensor has an absorber thickness of 37 mm to detect mainly the alpha particles emitted from  $^{214}\text{Po}$  (7.69 MeV) formed from the eventual decay of  $^{218}\text{Po}$ ,  $^{214}\text{Pb}$  and  $^{214}\text{Bi}$  atoms deposited on it. This thickness mainly ensures that lower energy alpha emissions (from the gases and other airborne alpha emitters) do not pass through the absorber.<sup>4</sup> In order to avoid uncontrolled static charges from affecting the deposition rates, aluminized side of the mylar was chosen to act as the deposition surface.<sup>5</sup>

For measuring indoor radon concentrations the detectors were exposed for a minimum of 90 days using dosimeter, which was hanged overhead on the ceiling at the height of minimum 1.5 m from the floor and at least 10 cm away from any surface. Dosimeters and DRPS were exposed simultaneously adjacent to each other for the same duration. The exposed films were then etched using 2.5N NaOH solution at  $60^\circ\text{C}$  for 90 mins for clear visibility of tracks for counting. The tracks recorded in this SSNTD films were then counted using a spark counter. The track densities were converted into concentrations using a significant calibration factors. The radon and progenies concentrations were related to find the equilibrium factor as well as inhalation dose of indoor radon.

Formulae used in calculations were:

*Radon concentration*

$$C_R (\text{Bq}/\text{m}^3) =$$

$$\frac{T_P}{\text{Calibration factor} \times \text{Exposure period (days)}} \quad (1)$$

where  $C_R$  is the radon concentration in  $Bq/m^3$  and  $T_P$  is the track density of films (Tracks/cm<sup>2</sup>) in pin hole compartment.

*Equilibrium Factor for radon*

$$F_R = \frac{EERC (Bq/m^3)}{C_R (Bq/m^3)} \quad (2)$$

where  $C_R$  is the concentration of radon calculated using track density from pinhole compartment and *EERC* is the Equivalent Equilibrium Radon Concentration.

*Inhalation dose of radon*

$$D = [(0.17 + 9 F_R) C_R] \quad (3)$$

where numerical numbers are the dose conversion factors for gas and progeny concentrations.<sup>1</sup>

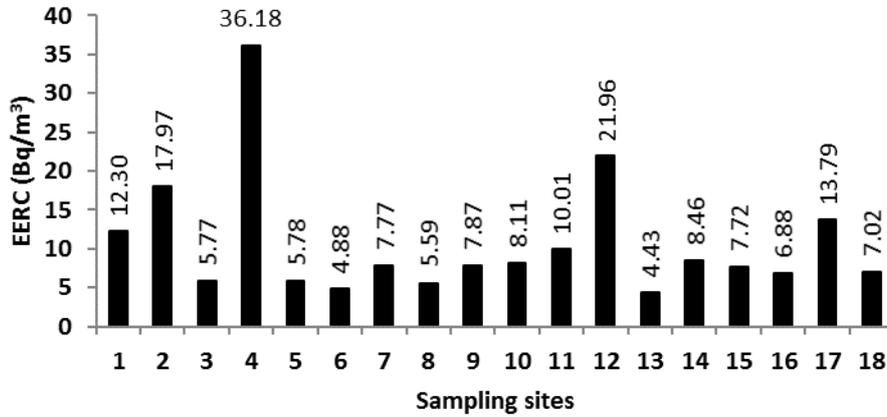


Figure 1. Equivalent equilibrium radon concentration in the study area.

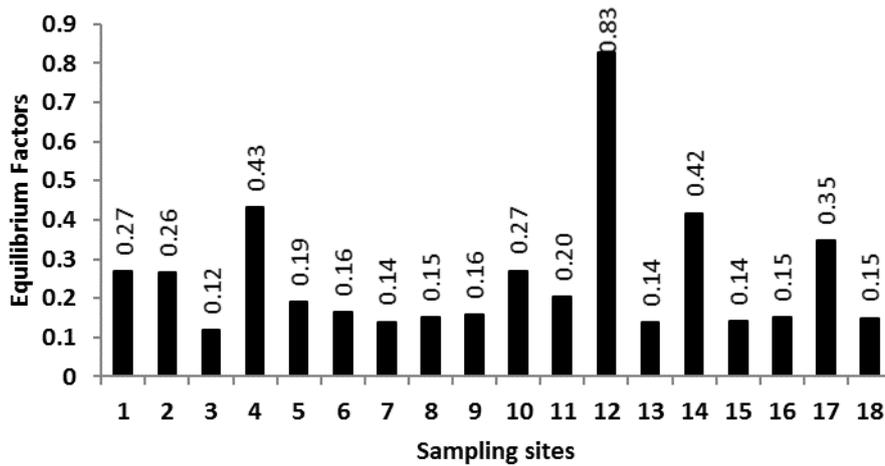


Figure 2. Equilibrium factor of radon in the study area.

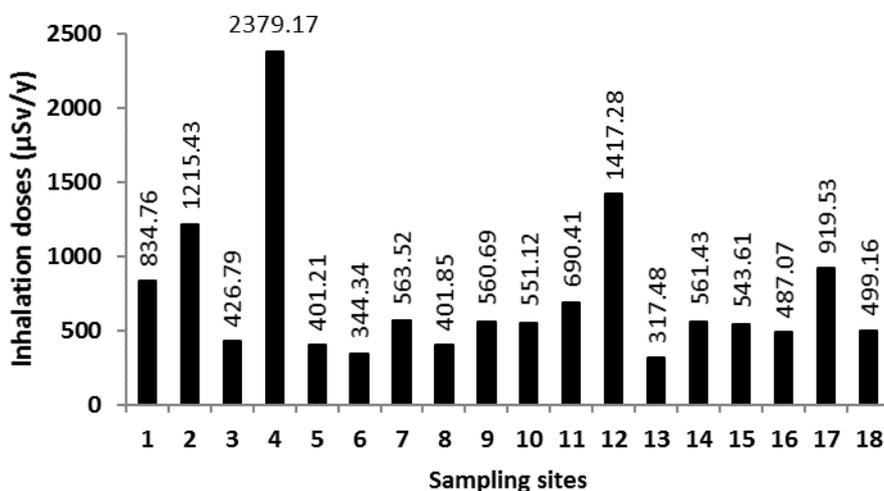


Figure 3. Annual inhalation dose of indoor radon in the study area.

$F_R$  represents the equilibrium factor of radon and  $C_R$ , the radon concentration respectively.

## RESULTS AND DISCUSSION

Due to limited source, a total of 24 DRPS were exposed in Aizawl City for a period of one year. Among the 24 exposed detectors, 18 detectors were retrieved undamaged or undisturbed. The concentrations of radon varied from 17.70 Bq/m<sup>3</sup> to 74.53 Bq/m<sup>3</sup> with a geometric mean of 40.17 Bq/m<sup>3</sup> and 1.39 GSD. The radon concentrations obtained in this work lies in the range covered by nationwide survey result<sup>6</sup> as well as the ICRP regulations.<sup>7</sup>

Figure 2 is the average EERC values which were obtained from the DRPS. The experimentally determined annual average value of EERC ranges from a minimum of 4.43 Bq/m<sup>3</sup> to a maximum of 36.18 Bq/m<sup>3</sup> with a geometric mean of 9.01 Bq/m<sup>3</sup> and GSD 1.71.

In the present work, using dosimeters and direct progeny sensors, direct calculation of equilibrium factor becomes possible from the experimentally determined values of the progeny concentrations along with the concentrations of the parent nuclides. The calculated annual aver-

age value of equilibrium factor of radon ranges from a minimum of 0.10 to a maximum of 0.86 with a geometric mean of 0.32 and GSD 1.66. This experimentally obtained result is slightly lower as compared to the globally assumed value of 0.4 for indoor environment, specified by UNSCEAR.<sup>1</sup> The annual average value of equilibrium factors of radon in the study area is shown in Figure 3.

The obtained annual average of inhalation dose of indoor radon range from 317.48 µSv/y to 2379.17 µSv/y with a geometric mean of 624.89 µSv/y with 1.67 GSD. Figure 4 shows the annual inhalation dose of radon in the study area. As in the case of F-factor, annual indoor radon inhalation dose is found to be lower than the global average value which is 1009 µSv/y.<sup>1</sup>

## ACKNOWLEDGEMENT

The authors are thankful to the residents of dwellings in Aizawl City for allowing the detectors to be placed in their bed rooms. The authors would also like to acknowledge research funding from Board of Research in Nuclear Sciences (BRNS), Department of Atomic Energy (DAE), Government of India.

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