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Variability of radon and thoron equilibrium factors in indoor environment of Garhwal Himalaya

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ABSTRACT

The measurements of radon, thoron and their progeny concentrations have been carried out in the dwellings of Uttarkashi and Tehri districts of Garhwal Himalaya, India using LR-115 detector based pin-hole dosimeter and DRPS/DTPS techniques. The equilibrium factors for radon, thoron and their progeny were calculated by using the values measured with these techniques. The average values of equilibrium factor between radon and its progeny have been found to be 0.44, 0.39, 0.39 and 0.28 for rainy, autumn, winter and summer seasons, respectively. For thoron and its progeny, the average values of equilibrium factor have been found to be 0.04, 0.04, 0.04 and 0.03 for rainy, autumn, winter and summer seasons, respectively. The equilibrium factor between radon and its progeny has been found to be dependent on the seasonal changes. However, the equilibrium factor for thoron and progeny has been found to be same for rainy, autumn and winter seasons but slightly different for summer season. The annual average equilibrium factors for radon and thoron have been found to vary from 0.23 to 0.80 with an average of 0.42 and from 0.01 to 0.29 with an average of 0.07, respectively. The detailed discussion of the measurement techniques and the explanation for the results obtained is given in the paper.

1. Introduction

Radon, thoron and their decay products are present in the indoor environment since their parent nuclei radium and thorium are present in building materials and the soil. It is well known that the inhalation of radon, thoron and their decay products contributes a major part (more than 50%) of the natural background radiation dose to the humans (UNSCEAR, 2008). Further, in the indoor environment, the inhalation doses due to the radon and thoron are predominantly contributed from their decay product concentrations in the indoor environment. The estimation of equilibrium factors for radon, thoron and their progeny is very important for assessing the radiation dose received from the inhalation of radon, thoron and their progeny. Therefore, it is very essential to carry out the systematic long terms measurements of the equilibrium factors for radon and its progeny and thoron and its progeny in the dwellings of the general public.

In case of radon exposure, the short lived radon progeny imparts radiation dose to lungs mainly and not the gas concentration itself. Radiation exposure due to radon progeny is estimated as the product of potential alpha energy concentration (PAEC) and the exposure time. The ratio of potential alpha energy concentration to the radon concentration can be substituted by the equilibrium factor (F), which is expressed as (Leung et al., 2006):

$$F = \{0.105\ C_1 + 0.515\ C_2 + 0.380\ C_3\}/C_o$$

where, C_o, C_1, C_2 and C_3 indicate the activity concentrations (in Bq/m^3) of ^{222}Rn, ^{218}Po, ^{214}Pb and ^{214}Bi, respectively.

In the past, radiation dose to the lungs due to exposure of radon progeny has been estimated by first measuring the radon gas concentration and then applying the equilibrium factor, considering the assumed value (0.4) of equilibrium factor for radon and its progeny (ICRP, 1991; UNSCEAR, 2008). However, the radon progeny and hence the equilibrium factor depends largely on the environmental conditions such as hours and modes of ventilation, humidity, etc (Porstendorfer, 1984; Jilek et al., 2010). The equilibrium factor has also been found to vary with time and place (Nikezic and Yu, 2005; Ramola et al., 2003; Yu and Nikezic, 2011; Yu et al., 1996). The ventilation conditions of a building and the

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plating out of radon and thoron progeny atoms onto surfaces also affect the equilibrium factors for radon and thoron (Ramola et al., 2003). In contrast, thoron equilibrium factor varies significantly even for the same environment. This is mainly due to wide variation of thoron concentration arising from its short lived nature. The very short half life of thoron results in non-uniformity of thoron concentration in the indoor environment. Hence it is not advisable to estimate EEC of thoron using the gas concentration and equilibrium factor. Therefore assumed worldwide value of equilibrium factors cannot reflect the actual results and there is a need of direct measurement of radon and thoron decay products concentrations to assess the actual dose received by the general public due to the exposure of progeny. In this study, direct measurements of the decay products and gas concentrations were carried out by using direct progeny sensors and pin-hole dosimeter technique, respectively. The equilibrium factor was then calculated simply by dividing progeny concentration by the gas concentration. The measurements have been taken in 87 houses of Uttarkashi and Tehri areas of Garhwal Himalaya for first quarter (rainy season) and then 57 houses out of these 87 were chosen for seasonal variations.

2. Study area

The Geographical maps of the study area are shown in the Figs. 1 and 2. The study area comprises of Tehri Garhwal and Uttarkashi districts of Uttarakhand, India. The map was prepared with Surfer software using Lambert Conformal Conical (LCC) according to NNRMS (2005) and transform formulae (Snyder, 1987). The sampling locations are shown in Fig. 2.

3. Experimental methods

3.1. Measurement of indoor ^{222}Rn and ^{220}Rn concentrations

Measurements of ^{222}Rn and ^{220}Rn were carried out by LR-115 Type II detector based pin-hole dosimeter technique. The dosimeter is a cylindrical plastic chamber and consists of two equal compartments separated by a central disc, each compartment having a length of 4.1 cm and radius 3.1 cm. Four pin-holes, each having a length of 2 mm and 1 mm diameter are made on this circular disk in order to discriminate ^{220}Rn. The dosimeter has only one entrance through which the gas enters the first chamber namely "radon + thoron" compartment through a 0.56 μm glass fibre filter paper and subsequently diffuses to second chamber called "radon" chamber cutting off the entry of thoron into this chamber because of its very short half-life of 55.6 s compared to that of radon (3.825 days). The LR-115 detector films are fixed at the end of each compartment. The device has been calibrated in a laboratory facility at Bhabha Atomic Research Centre, Mumbai in order to find a correlation between tracks registered on the detector films and the concentration of radon/thoron (Sahoo et al., 2013). The alpha emissions from radon and thoron produce the tracks on LR-115 detector film placed at the end of first chamber while as there is only radon and not thoron in the second chamber, the tracks are registered on the LR-115 detector film placed at the top of this chamber due to the alpha emissions of radon only. The dosimeters were suspended indoor overhead on the ceiling at the minimum height of 1.5 m from the ground and at least 10 cm away from any wall surface for a period of about 3 months.

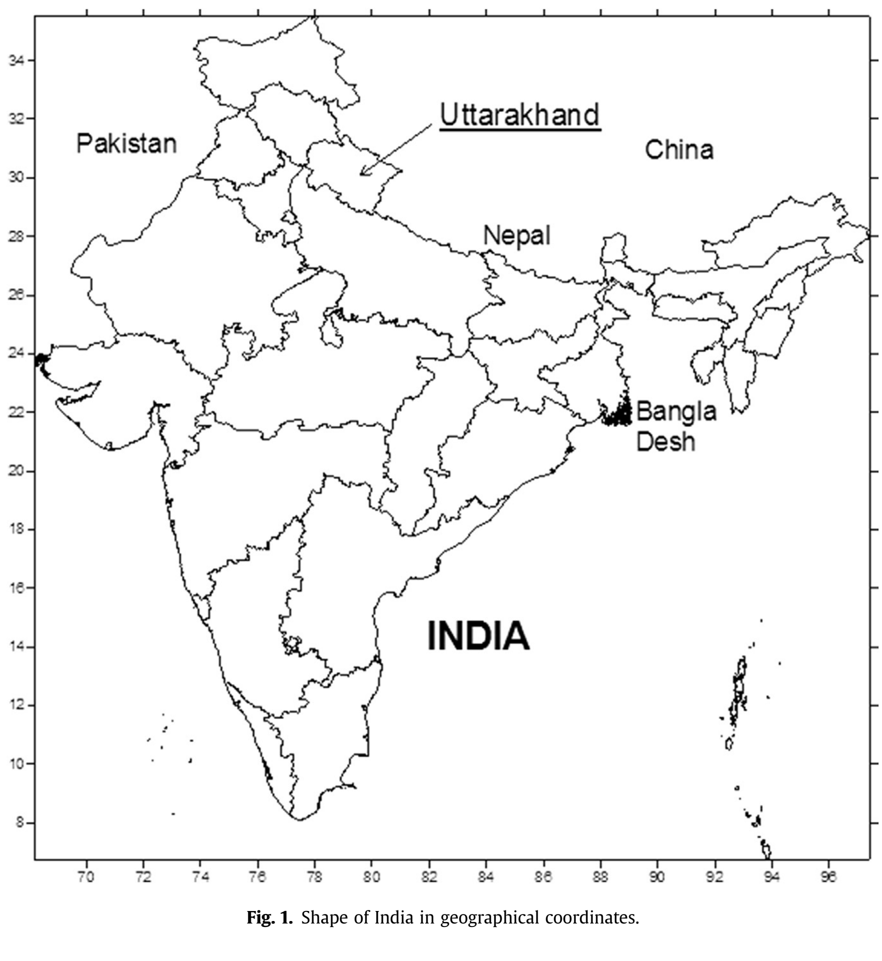

Fig. 1. Shape of India in geographical coordinates.