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Measurement of indoor radon–thoron concentration and radon soil gas in some North Indian dwellings

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A R T I C L E I N F O

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A B S T R A C T

The indoor radon, thoron and their decay products are the main contributors of total inhalation dose in the living environment. Radon soil gas concentration is about thousand times higher as compared to environment. Thus, it is necessary to measure indoor radon–thoron and radon soil gas underneath the soil. Keeping this in mind the measurements of radon and thoron in the indoor environment in some parts of Northern Haryana, India were carried out using twin cup dosimeters along with radon soil gas underneath the soil. The calibration factor for these dosimeters was measured during repeated experimental exercise and verified for two different depths. The radon and thoron concentration in the dwellings varied from 17 to 51 Bq/m^3 and 9 to 73 Bq/m^3, while the radon soil gas varied from 2.80 kBq/m^3 to 6.46 kBq/m^3. The radon soil gas and indoor radon–thoron concentration strongly depend upon the geological formations. A good correlation was found between the indoor radon and thoron concentration for mud houses.

1. Introduction

The radon–thoron and their solid decay products contribute 55% of the total inhalation doses to human population (Kullab et al., 2001; UNSCEAR, 1988). Thus it is important to study the indoor radon–thoron levels and their decay products in the environment and radon soil gas (Durrani and Ilic, 1997; Mehra and Bala, 2013). The indoor radon–thoron levels depend upon various factors like geological setting of area, nature of soil, meteorological conditions, living style of the dwellers and type of building material used for the house construction (Mehra et al., 2011; Plant and Saunders, 1996; Singh et al., 2011). The major part of indoor radon–thoron comes from the soil and building materials, because the uranium and radium are uniformly distributed in these materials from the time of origination of earth (Gupta et al., 2009; Khatibeh et al., 1997; Kumar et al., 2003; Patra et al., 2013). The radon is a radioactive gas which is produced just after radium and exists in three isotopic forms; radon (^{222}Rn), thoron (^{220}Rn) and actinon (^{219}Rn). The most stable is radon-222 having a half life of 3.824 days and is assumed to be the most effective as compared to thoron and actinon. The radon and thoron decay into their decay products namely polonium, bismuth and lead which are stable nuclei. The decay products of radon and thoron are more dangerous as compared to their parents. The radon and thoron are the gases inhaled in the human body through the nose or mouth and exhaled outside due to small lung residency time, while the decay products of radon and thoron are solid phase that get attached to dust and form aerosol particles. These aerosols are inhaled, get deposited on the respiratory tracts and impart alpha energy to lung and tissue. The alpha energy imparted to the lung causes damage to tissue and cell, which ultimately leads to the initiation of cancer. The radon is the second leading cause of lung cancer after smoking even for those people who never smoked (ICRP, 2010; UNSCEAR, 2009; WHO, 2009) and for the people living in the high background radon area (HBRA). The soil is the never ending source of radon and thoron, because it contains uranium and thorium with a half life of 4.5 billion years. The radon gas concentration inside the soil is 10^3–10^4 times higher than that of the environment (Chauhan and Kumar, 2013). The radon gas at the surface of the soil is continuously diluted while inside it increases with depth (Jonsson, 2001). The depth dependence of the soil radon level was discussed in several reports and sometimes in connection with the ideas of the transport of the radon gas from deep layers (Abumurad et al., 1997; Tanner, 1964). The measurement of ^{222}Rn concentration in soil gas can be used as a method for evaluating the potential for elevated indoor ^{222}Rn concentrations (Singh et al., 2011). Since the source of indoor radon is soil gas, thus there may exist a correlation between the radon soil gas and indoor radon. The objective of the present work is to carry out the measurement of indoor radon and thoron concentration in dwellings. The data on the radon soil gas from the north Haryana is not available in the literature. The high radon soil gas in any particular area shows the

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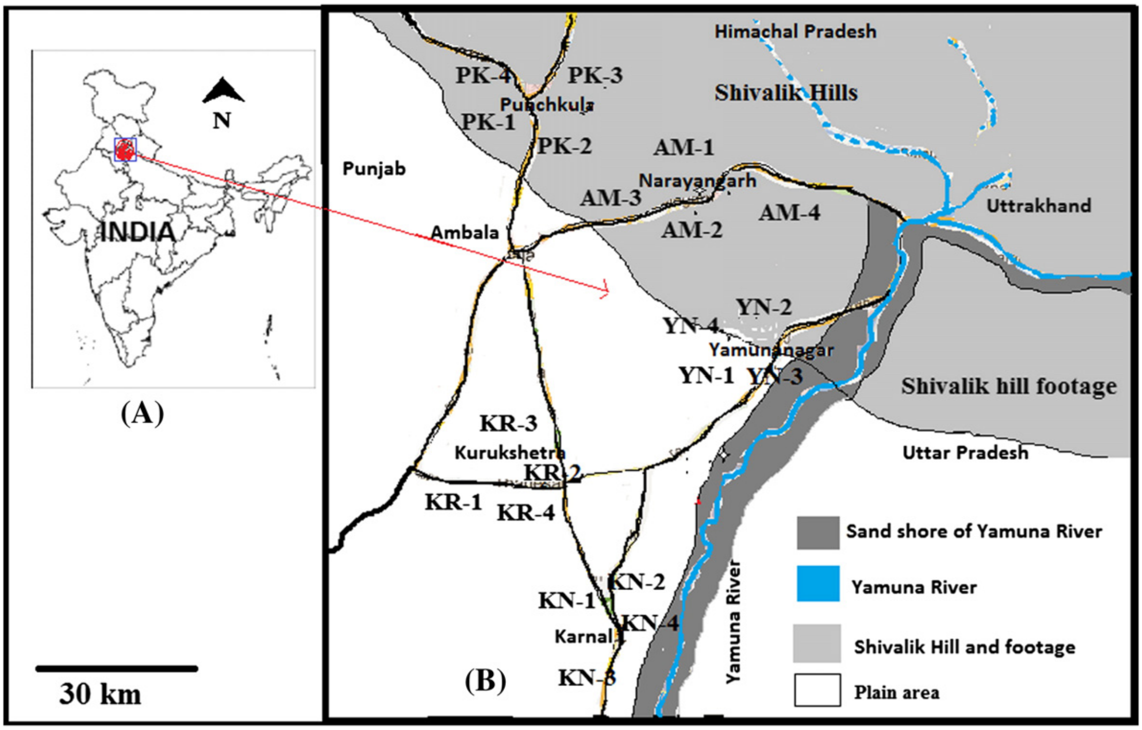

Fig. 1. (A) Location of the study area in Indian map. (B) The study area.

possibility of uranium and can be used for uranium exploration. Keeping this in mind, the indoor radon–thoron concentration and radon soil gas at a depth of 50 cm from the soil surface in some parts of Northern Haryana (India) were carried out.

2. Description of the study area

Haryana is located 27°37′ to 30°35′ N latitude and between 74°28′ and 77°36′ E longitude. The altitude of Haryana varies from 700 to 3600 ft (200 m to 1200 m) from sea level. Haryana has four main geographical features viz. Yamuna–Ghaggar, plain forming the largest part of the state from which sand is transferred to all over Haryana for building construction, Shivalik hills to the northeast, semi-desert sandy plain to the southwest, and the Aravalli range in the south. The state is bounded north by Himachal Pradesh, east by Uttar Pradesh, south and west by Rajasthan and northwest by Punjab. Delhi forms an enclave on its eastern boundary. The area selected for the present study is located at the foot of Shivalik hills, where soil transformed from the mixture of sand, stones and rocks. Five provinces namely Kurukshetra, Karnal, Ambala, Yamunanagar and Panchkula were selected for the indoor radon–thoron study and measurements of radon gas as shown in Fig. 1. Out of the five districts under study the Ambala, Panchkula and Yamunanagar are situated at the foot of Shivalik hill, while the Kurukshetra and Karnal are situated on the plain area on southwest of Shivalik hill. Some part of the study area is alluvial plain and divided into two units; the upland plain and low-lying areas. These districts are entirely covered by 58% alluvial deposits of quaternary to recent age consisting of sand with kankar, gravel, and cemented and unconsolidated sand containing long lived uranium and thorium. The radon diffusion coefficient through sand is higher than that of clay, thus a deeper soil contributes to indoor radon (Hassan et al., 2009). These materials when used for building construction contribute to the indoor radon along with soil. The gray legends in Fig. 1 show the Shivalik hill slope to the south having different kinds of stone and rock formations while the white legends are for plain area having soil transformed from stone to rocks from Shivalik hills.

3. Materials and methods

3.1. Measurement of indoor radon–thoron concentration

The measurement of indoor radon–thoron levels in the area under study was carried out by twin cup dosimeter developed at the Bhabha Atomic Research Centre (BARC), using 12 μm thick LR-115, type II, cellulose nitrate based SSNTDs manufactured by Kodak Pathe, France and used by many investigators (Mehra et al., 2011; Virk and Sharma, 2000).

Twin cup dosimeter consisted of two cylindrical chambers having a length of 4.1 cm and a radius of 3.1 cm (Fig. 2). The SSNTD1 placed in compartment M measures radon alone which diffuses into it from the ambient air through a semi-permeable membrane (latex, cellulose nitrate etc.) of 25 μm thickness having diffusion coefficient in the range of 10^{-6}–10^{-7} cm^2 s^{-1} (Abdel and Somogyi, 1986). It allows the build-up of about 90% of the radon gas in the compartment and suppresses thoron gas concentration by more than 99%. On the other hand, the glass fiber filter paper in the compartment F allows both radon and thoron gases to diffuse in, thus, the tracks on SSNTD2 placed

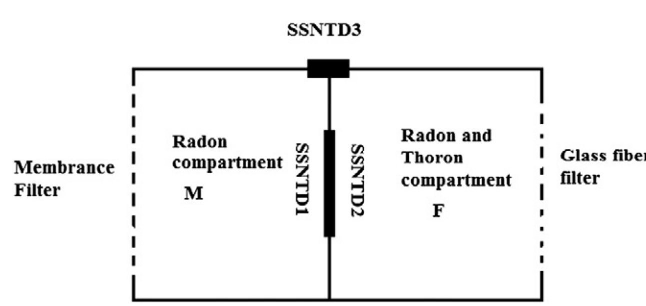

Fig. 2. Schematic diagram of twin cup dosimeter used in the study.