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The correlation between indoor and in soil radon concentrations in a desert climate

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HIGHLIGHTS

- We measured indoor and soil radon concentrations for the eastern desert of Jordan.
- The average indoor radon concentration in the eastern desert of Jordan is 29.6 Bq m^{-3}.
- The average soil radon concentration in the eastern desert of Jordan is 7.53 kBq m^{-3}.
- We found a moderate correlation between indoor and in soil radon concentrations.

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ABSTRACT

This study examines the levels and the correlation between indoor and in soil radon concentration in a desert climate. The measurements are carried out, in Jordan desert in AlMafraq district, using the passive integrated technique. An intelligent automated tracks counting system, modified recently by our group, is used to estimate the overlapping tracks and to decrease the counting percentage error. Results show that radon concentration in soil expands from 4.09 to 11.30 kBq m^{-3}, with an average of 7.53 kBq m^{-3}. Indoor radon concentrations vary from 20.2 Bq m^{-3} in the AlMafraq city to 46.7 Bq m^{-3} in Housha village and with an average of 29.6 Bq m^{-3}. All of individual indoor radon concentrations are lower than the limit (100 Bq m^{-3}) recommended by WHO except two dwellings in Housha village which found being higher than this limit. A moderate linear correlation (R^2=0.66) was observed between indoor and in soil radon concentrations in the investigated region. Our results showed that an in soil radon measurement can be a satisfactory predictor for indoor radon potential.

1. Introduction

Radon, ^{222}Rn is a noble gas, generates from the decay of radium, ^{226}Ra, which is a member of the Uranium, ^{238}U decay chain. Radon found in soil, rocks and water all over the earth. Radon in soil is the main source of indoor radon. The air pressure indoors is slightly lower than the air pressure in the soil underneath and/or surrounding the home. This causes the radon gas in the soil to draw, through any openings, cracks or gaps and drains in the foundations, inside homes. Also, high concentration of radon in soil compared to that indoors increases the level of radon leakage inside doors through cracks or holes in the foundations by diffusion process. Radon is considered a significant contaminator that affects indoor air quality worldwide. Furthermore, the indoor radon and its decay products have been known as a significant contributor which increases lung cancer risk in the population (Field et al., 2001). According to the World Health Organization (WHO) radon is the most frequent cause of lung cancer after cigarette smoking. The indoor radon level depends on various factors like geological setting of area, nature of soil (soil permeability, soil moisture content, porosity, and the uranium content of soil), meteorological conditions, type of building material used in house construction and living style of the dwellers (Ennemoser et al., 1995; Singh et al., 2011). The soil and the bedrock beneath and/or surrounding the building represent the main source of indoor radon concentration. Therefore, the measurement of the radon concentration in soil can be used as an indicator and a predictive method to evaluate the elevated indoor radon concentrations (Reimer et al., 1989; Farid, 1997; Varley and Flowers, 1998a; Vaupotič et al., 2002; Iskandar et al., 2005).

Several research papers were devoted to correlate indoor radon concentration to its concentration in soil (Varley et al., 1998; Singh

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et al., 2010; Antoci et al., 2007; Farid, 1997; Chauhan et al., 2014; Kumar and Chauhan, 2014; Chen and Ford, 2016; Celik et al., 2008; Mihci et al., 2010; Åkerblom et al., 1984; Varley and Flowers, 1998a, 1998b; Albering et al., 1996; Reimer and Gundersen, 1989; Kemski et al., 2009; Barnet et al., 2004, 2006; Barnet et al., 2008 and Appleton and Miles, 2010). The measurements of radon in soil reported that the radon flow from soil depends not only on the radium content and its distribution, but also on the permeability, porosity, moisture content, and meteorological parameters (Koarashi et al., 2000; Lara et al., 2015; Almayahi et al., 2013). The relationship between soil gas and indoor radon concentration differs according to the geographical nature of each region, whereas each region has its own geology, housing construction and occupants' lifestyle. Water content of the region has a large influence on the emanation and the soil transport parameters for radon which will reflect on the in soil radon concentration (Stranden et al., 1984). It had been investigated experimentally as well as theoretically that elevated moisture in the soil stimulates radon emanation. At the soil saturation point, radon diffusion and emanation will decrease (Nielson and Rogers, 1994). It is known that permeability of the soil may change by various orders of magnitude within a very small area of few squared meters.

The primary goal of this work is to estimate the potential of soil gas measurements in the prediction of indoor radon concentrations for desert region in Jordan. Another objective of this work is to measure indoor radon concentration in one of Jordan desert district and compare it to the permissible level recommended by WHO (Zeeb and Shannoun, 2009).

2. Region of study

AlMafraq (Fig. 1) is one of the Jordanian districts, located northern east of the capital Amman and occupied by about of 320,000 resident which represents up to 5% of total population of Jordan. AlMafraq district ranked as the second largest area among Jordanian districts and the second smallest population density after Ma'an. The climate of AlMafraq is characterized by a hot dry summer and cold winter with very little rainfall (about 150 mm per year). The driest weather is in June, July, and August when no rainfall occurs. The wettest weather is in January when an average of 36 mm of rainfall occurs.

3. Material and methods

The time-integrated passive radon dosimeter inclosing the CR-39 solid state nuclear track detectors (SSNTDs) were used in this study. The CR-39 detectors were purchased from Pershore Moulding Ltd., U.K. The schematic diagram of the dosimeters is shown elsewhere (Al-Kofahi et al., 1992; Al-Bataina et al., 1997).

In a summer season where as dwellings windows and doors are usually kept open most of the time, about 520 dosimeters were distributed over 13 villages in AlMafraq district including AlMafraq city itself. In each village 20 dosimeters were used for measuring indoor radon concentration and another 20 for in soil radon measurements. All the dwellings selected for the study have no-air conditioning system for cooling or heating. Dwellers use windows and doors for ventilation; also they have identical architectural

Fig. 1. Map of Jordan.