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Influences on indoor radon concentrations in Riyadh, Saudi Arabia

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HIGHLIGHTS

- Limited information about indoor radon in Riyadh.
- Several factors influence Radon level were investigated in 786 dwellings in Riyadh over one year.
- Some results are over the action level and are advised to improve their ventilation systems.

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ABSTRACT

The influences on indoor radon concentrations in Riyadh, Saudi Arabia survey was carried out for 786 dwellings. The measurements were obtained by using a passive integrating ionization system with an E-Perm® Electret ion chamber. Radon levels ranged from 1 to 195 Bq m^{-3}, with a mean value of 24.68 Bq m^{-3}, the geometric mean and the geometric standard deviation are 21 and 2 respectively. 98.5% of the results were below the action level recommended by WHO of 100 Bq.m^{-3}. The results were found to vary substantially due to types of houses and rooms, ventilation, seasons and building materials. Radon concentrations were higher in houses with no ventilation systems, and central air conditioners, and were relatively lower in well ventilated houses with red bricks and water air conditioners.

1. Introduction

Radon is a naturally occurring radioactive, colorless, odorless gas that is continuously released by natural sources, such as geological formations in soil and construction materials. The inhalation of radon ^{222}Rn and its radioactive daughters, even for people exposed to low radon levels that may be found in residential buildings (WHO, 2009), increases the chance of developing lung cancer (UNSCEAR, 1993, 2000). When inhaled, radon particles carrying daughters enter and stick onto the bronchial air passages, irradiating and damaging the surrounding cells. Based on national and worldwide investigations, several agencies have concluded that radon is a known cancer causing agent in humans and is the second most common cause of lung, skin, and leukemia cancers after smoking (WHO, 2009; EPA, 2007A; ICRP, 1993).

No level of radon is considered safe. In fact, many countries set their national exposure levels based on their own studies. The American Environmental Protection Agency (EPA, 2007a) limits radon action level of 148 Bq m^{-3}. This reference represents the acceptable indoor radon level in order to limit the risk to individuals and alert them when action should be taken. In Europe, the reference level varies depending on the age of the building. Some European countries have more than one reference level, but in general it does not exceed 400 Bq m^{-3}. The Commission of the European Communities (CEC, 1990) has recommended two action levels, 200 Bq m^{-3} for new homes and 400 Bq m^{-3} for old and existing homes. In the meanwhile, some countries that have not determined a national reference level, such as Saudi Arabia, have adopted WHO action reference levels of 100 Bq m^{-3} to minimize health hazards due to indoor radon exposure.

Only limited radon data for locations in Saudi Arabia have been published (Abu-Jarad and Al-Jarallah, 1986; Garawi, 1996; Al-Jarallah et al., 2003a, b). The average radon concentration was 22 Bq.m^{-3} after an indoor radon survey made by Al-Jarallah et. Al. (2003a) of nine cities in the Eastern and the Western provinces of Saudi Arabia. A total of 724 houses and 98 schools were included.

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More investigations and surveys are still needed and are being carried out to add new building types and locations to the data base, and to review existing data using different instruments and methods.

A national project was established (Aleissa et al., 2012) to reduce the impact of indoor radon exposure by raising awareness, advising the general public of radon hazards and the potential health risks, and encouraging people to take the appropriate actions to reduce radon levels if necessary. The current study investigated the distribution of indoor radon concentrations in Riyadh, Saudi Arabia to further identify which factors were correlated with indoor radon concentrations.

2. Material and methods

2.1. Housing description and sampling circumstances

Riyadh is located at 24° 38′ 26″ N, 46° 46′ 22″ E at approximately 630 m above sea level. The population of Riyadh is more than six million, living on about 5000 km^2 of land. It has a hot arid desert climate with an average high temperature of 44 °C in the summer and a cold with an average temperature of 8 °C during winter. The day–night variation in outdoor temperature could be as high as 20–25 °C, however, this study was performed for the indoor dwellings air where the temperature is controlled by air conditioning which dramatically reduces the seasonal or night–day variation in the temperature, and it is also known to have many strong dust storms.

A wide range of traditional and modern accommodation types were investigated. In this work, radon detectors were distributed to more than 786 houses, focusing on the more populated areas in the city, which were assumed to represent all common types of houses in the study area. In order to represent all types of dwellings in the studied area, the radon concentration surveyed dwellings types roughly followed the distribution of the dwelling types in the studied area which is provided by Saudi Central Department of Statistics and Information (CDSI, 2009). The followed dwellings distribution was 24% for apartments, 10% for town houses, 42% for villas, 9% mud brick houses, and 15% for other types of houses. In addition to the dwelling selection criteria (e.g., type of building material, dwelling size, geographical locations etc.), the dwellings were selected randomly based on distribution percentage in each criteria as shown in Table (1). Most of these buildings were constructed from bricks and concrete. Two detectors were used in all two stories villas, a third was used for basements, and only one detector was used to measure the remainder of dwellings.

This project was performed in collaboration with the Ministry of Education, and physics and chemistry teachers were involved as primary contacts to introduce and discuss project ideas with study participants. These teachers explained the responsibilities of the participants to follow all instructions during the period of measurement, including the placement of the detector at the lowest level of the house, in basements, living areas, and/or bedrooms, All participants were recommended to place the detector 1 m above the ground, at least 30 cm from any objects, and at a similar distance from doors or windows or any voltage source. Furthermore, a brochure was provided to explain the significance of radon gas and its sources, as well as it shows how radon enters the buildings, health risks, and the detection system. The participants in the survey were instructed to record the time and date of the start and end of the measurement. To ensure a high quality of measurement, canisters were routinely checked for performance using a voltage reader and reference electret. One duplicate detector was installed for every 25 detectors distributed to calculate the measurement error.

2.2. Radon measurements

The study was designed to record radon levels of 786 dwellings over one year using more than 1100 detectors (Electret Ion Chamber from E-PERM, Rad Elec Inc., Frederick, MD 21701, USA). The detector is a time-integrated passive device consisting of a disk detector (electret) placed at the bottom of a plastic canister (ion chamber). Prior to deployment, the electret is kept covered by a spring-loaded screw cap. Once the cap is released, Radon gas enters the canister via passive diffusion through a filtered inlet (Kotrappa et al., 1990, 1993). This filter will not allow the radon daughters products (RDP) to enter, such that all RDP are produced via radon decay inside the canister. When the disk is exposed, the positively charged electret collects the negative ions formed by the interaction of radiation emitted by radon and its daughters with the air inside the collection chamber. The resulting decrease in charge is related to the concentration of radon integrated over the period of measurement, according to equation (1) (Kotrappa et al., 1990).

$$C = \frac{V_i - V_f}{\mathrm{CF} \times t} - \mathrm{BKG} \tag{1}$$

where:

C is the average radon concentration in Bq.m^{-3}.
V_i is the beginning voltage on electret before exposure.
V_f is the final voltage on electret after exposure.
CF is the calibration factor in Volts Bq.m^{-3} d^{-1}, which is calculated as

$$\mathrm{CF} = 5.1 \times 10^{-2} + 1.7 \times 10^{-5} \times \text{voltage midpoint}.$$

t is the exposure time in days.
BKG is the gamma background correction in Bq.m^{-3} (8.7 Bq.m^{-3} per μSv h^{-1}).

In this survey, the “S” size (210 mL) canister of Electret Passive Environmental Radon Monitor (E-PERM) was used with two types of electrets. The more sensitive short-term (ST) disk becomes depleted of charge more rapidly than the less sensitive disk that used for measuring long-term (LT) exposure. The calibration of the electrets was done in the Rad Elec Inc. In addition, the electrets were divided into 10 groups according to their previous response. For each group, 3 electrets were selected and exposed to a ^{226}Ra radioactive standard which was placed at the bottom side of the top cover of a 3720 mL accumulator jar. The jar was covered by a radon leak-tight lid, and left for one month to ensure the secure equilibrium between the ^{226}Ra and its daughter ^{222}Rn. Moreover, 50 detectors were tested at the laboratory of the health and environmental center at KACST to ensure the quality assurance. The reader device was tested by using the reference package (RT) from Rad Elec Inc. The uncertainty ($\pm\sigma$) was estimated in all calibration measurement not to exceed 5% of the calculated values.

By utilizing the appropriate electret, EICs can make integrated measurements from a few days up to one year. Based on preliminary lab trials and experiments, an optimum measurements period was estimated to be 19–20 days to achieve the highest practical measurements sensitivity for the ST electrets and up two six months for the LT electrets. Due to the large number of