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Evaluation of radon related parameters in environmental samples from Jazan city, Saudi Arabia

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A B S T R A C T

Environmental samples like soil, building materials and decorative materials are the major source of indoor radon. The contribution of these environmental materials toward indoor radon level depend upon the radium content and radon exhalation rates and can be used as a primary index for radon levels in the dwellings. Sealed cup technique was used to determine the radon exhalation rates and the effective radium content in different environmental samples collected from Jazan city, Saudi Arabia.

Back diffusion is the main removal processes of radon from its sealed cup which leads to underestimate the measured parameters. To assure the quality of the measurements, the results were corrected for back diffusion effect and checked for the effect of sample mass on the measured parameters. The combined uncertainty was also calculated taking into consideration the possible sources of uncertainty.

The overall weighted mean of areal exhalation rate (E_A) and effective Radium content (Ra_{eff}) for soil samples collected from different 10 districts in Jazan city is 17.02 ± 2.06 Bq $m^{-2}d^{-1}$, 3.01 ± 0.37 Bq kg^{-1} respectively. For 20 Building materials samples, $E_A = 1.989 \pm 1.056$ Bq $m^{-2}d^{-1}$ and $Ra_{eff} = 0.351 \pm 0.186$ Bq kg^{-1}. Finally, for decorative materials (23 samples), $E_A = 1.225 \pm 0.136$ Bq $m^{-2}d^{-1}$ and $Ra_{eff} = 0.427 \pm 0.031$ Bq kg^{-1}. The maximum values of the measured parameters are found in the soil of scheme 5 and 6 district, red sand (building material) and gypsum (decorative material). As the mass of the sample increase, more and more radon diffused back into the sample and the measured effective radium content is reduced. After correcting the results for back diffusion effect, all masses approximately get the same value of effective radium content and then reduced the uncertainty in the weighted mean.

1. Introduction

Radon (^{222}Rn) is a noble gas and is formed by the decay of ^{226}Ra, which is one of the nuclides formed in the disintegration series from ^{238}U. The long half-life (3.824 days) and heavier nature of radon causes its higher accumulation in poorly ventilated dwellings. In 1988, the International Agency for Research on Cancer classified radon as a human lung carcinogen, based on a review of evidence from experimental data on animals and from epidemiological studies of underground miners (ICRP, 2010). Epidemiological studies confirm that radon in homes increases the risk of lung cancer in the general population. When radon is inhaled, its short lived progeny, ^{218}Po and ^{214}Po, which are solid, tend to be deposited on the bronchial epithelium, thus exposing cells to irradiation. The alpha particles emitted by these short-lived decay products of radon can damage cellular DNA. There is no known threshold concentration below which radon exposure presents no risk. Even low concentrations of radon can result in a small increase in the risk of lung cancer. The majority of radon-induced lung cancers are caused by low and moderate radon concentrations rather than by high radon concentrations, because in general less people are exposed to high indoor radon concentrations. Contribution of radon and its progeny to the total natural effective dose has been reported to be more than 50% (UNSCEAR, 2000).

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Indoor radon originate from the wall, floor and ceilings which are constructed of building material, rock or soil, by release from materials brought into the room, such as radon rich water or gas, and by radon in inlet air (UNSCEAR, 1982). The amount of radon formed in rocks and soils depends on their uranium/radium content. However, this alone is not decisive in determining the radon concentration in air, it is also determined by the extent to which the radon atoms formed actually emanates from the mineral grains and whether radon can leave the pore space either by diffusion or together with a flow of air or water. In addition, radon concentration in the soil air is significantly affected by the occurrence of moisture/water in the pores. Besides soil, construction materials may also significantly contribute toward the indoor radon (Durrani & Ilic, 1997). Permeability of the soil is a main factor affecting radon levels in dwellings. As the measurement of soil permeability is difficult, the effective radium content and the exhalation rates are thought to be a better indicator of radon risk and considered as the most important tools for the selection of building materials for construction. The magnitude of the exhalation progress is usually called the (surface) exhalation rate, which is defined as the number of radon atoms leaving unit surface area of the material per unit time ($Bqm^{-2}d^{-1}$), or the mass exhalation rate, which is defined as the number of radon atoms leaving unit mass of the material per unit time ($Bqkg^{-1}d^{-1}$). The former is more frequently used for evaluating the indoor radon concentration (Zhang et al., 2012).

There is considerable public concern about radon exhalation from building materials, especially those used for interior decoration like ceramic tile which considered as an important source that contributes to indoor radon concentration through exhalation from wall and floor.

For these reasons, this work is aimed to evaluate these radon related parameters in different environmental samples (soil, building and decorative materials) from Jazan city, Saudi Arabia using sealed cup technique as an advantage passive method. The used sealed cup is a glass cup fitted with solid state nuclear track detector such as CR-39.

2. Experimental set up and theoretical approach

2.1. Area under study

Jazan, also spelled Gizan, is one of the administrative regions of the Kingdom of Saudi Arabia, located in the south west of the Kingdom overlooking the Red Sea. The port of Jazan is the third port of the Kingdom on the red sea coast in terms of capacity. The region includes a number of governorates and administrative centers located in the eastern parts of the mountainous and western coastal highlands, which are characterized by their environmental and climatic diversity and are considered the main gateway to the Farasan islands. The Jazan region is one of the land ports connecting Saudi Arabia to the republic of Yemen as it is bordered on the south and south-east. Jazan is one of the Kingdom's richest agricultural regions, remarkable for both the quality and variety of its agricultural produce. It is notable for its production of coffee beans, grain crops and fruit (apples, bananas, lemons, mangoes, oranges, papayas, and plums). Jazan province has a population of above 1.5 million, according to a 2010 census which considered the most densely populated regions in Saudi Arabia. Its area is about 13,457 km^2 to be the second smallest region in the Kingdom after Al Baha area.

The area under study is Jazan city, the capital of the Jazan administrative region, lies between 16° 51′ and 16° 59′ North and 42° 32′ and 42° 38′ East. It has a population of about 157,536 inhabitants.

Building and decorative materials and soil from jazan city are the main environmental samples targeted by this study for radon related parameters measurements.

2.2. Samples types and preparation

Soil: The soil samples are collected from 10 different districts in Jazan city as listed in Table 1. For each district two to four samples are taken 15 cm below the surface with a total of 30 soil samples for all studied districts. The soil samples were dried at 100° and sieved out to be ready for measurement.

Building and decorative materials: The widely used building and decorative materials in Jazan city were collected and prepared for measurements as done for soil. The samples were collected from different shopping stores in Jazan city. The building materials are sand (9 samples), black cement (2 samples), gravel (4 samples) and bricks (5 samples). The decorative materials are white cement (5 samples), gypsum (4 samples), white premium fix (2 samples), water resist finish (2 samples) and ceramic tiles (15 samples). Three types of sand were collected (red, white and black) which used at different stages in construction but there is only one type of black cement (El-janoub) found in Jazan city. Also, two types of gravels (10 mm and 20 mm) and bricks (cement and red) were used in construction in Jazan city. For decorative materials there are only two types of white cement (Saudi and Egyptian) and one type of gypsy, premium fix and water resist (WR) finish. There are many types of ceramic tiles used in Jazan city among which we choose the brands of the following manufacture: Saudi (wall and floor), El-Ryiad, Eisa ben Laden (Italy) and El-Forsan.

The porosity ε, is experimentally measured using the following relation:

$$\varepsilon = \frac{Pour\ \ volume}{Total\ \ volume} = \frac{m_{wet} - m_{dry}}{\rho_w V_t}$$

where, m_{wet}, m_{dry} are the masses of wet and dry sample respectively. ρ_w is the water density and V_t is the total volume.

2.3. Sealed cup technique

A mass of 250 g from each sample was placed in a sealed glass cup of 9.25×10^{-4} m^3 volume with 8×10^{-3} m^2 sample surface area. Each cup was fitted with CR-39 (TASTRAK) detector placed in the top inside of the cup. The sensitive part of the detector was facing the emanated radon gas from the sample so that it could record the alpha particles resulting from the decay of radon and its daughters in the whole air volume of the cup. Such assembly was left for 85 days. The samples of gypsum, white sand and white cement are prepared at different masses ranged from 50 to 500 g to study the effect of the used mass on the emanation of radon. At the end of exposure period, CR-39 detectors are collected and etched together under their optimum conditions of 6.25 N NaOH at 70° for 6 h and counted under optical microscope of 400× magnification power.

The calibration factor of the sealed cup (K) is equal to 0.237 $Tcm^{-2}/Bqm^{-3}d$ with 1% uncertainty, with the condition that the sample volume equal or less 1/3 cup volumes (i.e $V_s \le 0.333$ V) as obtained from the work of Abo-Elmagd and Daif (2010) for the calibration process.

2.4. The measured radon related parameters

The concentration of radon emanated from the sample was allowed to build up with time t (day). The buildup of radon concentration C (t) verifying the following equation (Al-Jarallah, Abu-Jarad, & Fazal-ur-Rehman, 2001):