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Estimation of the residential radon levels and the population annual effective dose in dwellings of Al-kharj, Saudi Arabia

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ABSTRACT

Indoor radon levels and the annual effective dose are measured in Al-kharj city, Saudi Arabia dwellings using CR-39 detector. The dwellings are classified according their types (schools, homes and working area). The influence of some factors like number of floors and ventilation conditions on indoor radon levels, equilibrium factor and radon effective doses were studied. Can and bare method is used for determine the equilibrium factor between radon and its daughters. Based on the dosemetric approach and epidemiological determinations conversions convention for radon exposures, the annual effective doses are calculated and compared. The average radon concentration varies from 76 ± 38 Bq m^{-3} in work places to 114 ± 41 Bq m^{-3} in homes. About 77% of the studied dwellings give radon concentration in the range from 50 to 150 Bq m^{-3}. The overall weighted mean of radon level is equal to 94 ± 41 Bq m^{-3} which about 2.5 times the global average. The equilibrium factor has a wide range from 0.1 to 0.6 with overall weighted average equal to 0.308 ± 0.13. The variety of living style, constructed materials and ventilation rates are responsible for this wide range and subsequently the obtained high uncertainty (42%). Homes showed larger annual effective dose (3.186 ± 0.75 mSv) than other dwellings which locate in the range of the recommended action level but about three times the global average. The result shows that the ventilation condition is the major but not the only factor affects the results. Poor ventilated dwellings showed the maximum annual effective dose on the other hand the number of floor has insignificant difference.

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1. Introduction

Measurement of the indoor radon level is highly desirable because the radiation dose received by the human population due to the inhalation of radon and its progeny contribute more than 50% of the total dose from natural sources (UNSCEAR, 2000). After inhalation of radon, their decay products are deposited in the lung which receives a dose from alpha radiation emitted during subsequent decays. This has been associated with the induction of lung cancer (National Academy of Science, 1988; UNSCEAR, 2006). It is estimated that indoor radon exposure may be responsible for more than 10% of the US lung cancer incidence (Fabricant, 1990). The assessment of the radiation doses to humans from radon is of particular importance because they contribute significantly to the collective dose of the world population.

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, which may in turn have a normal concentration of the gases or an increased concentration derived from sources outside the room (UNSCEAR, 1982). The main factors that affect the variations of indoor radon levels are changes in the ventilation rate and temperature difference. The ventilation rate affects the air exchange rate between indoors and outdoors. Differences in temperature result in pressure differences between indoors and outdoors that create a driving force for radon to enter indoors. The temperature differences are because the outdoor temperatures vary widely during the day and night, while indoor temperatures may not change significantly. In general, residential radon is regulated by a reference level of radon concentration between 200 and 300 Bq m^{-3} based on ICRP recommendations (ICRP, 2010).

The passive measurement of radon concentration based on solid state nuclear track detectors (SSNTDs), is sufficiently simple and cheap and provides the possibility of large-scale surveys simultaneously for many measurements. The information, integrated over a long time interval (from several days to several months), gives reliable average values of the measured concentrations (Nikolaev & Ilic, 1999).

This study is aimed to survey the radon concentration in Al-kharj city, Saudi Arabia and calculate the annual effective dose to the populations based on UNSCEAR and ICRP recommendation.

2. Experimental set up and theoretical approach

2.1. *Area under study*

Al-kharj is a fast growing Saudi governorate and is located 77 km south of the Saudi capital (Riyadh). It is a main valley where several other valleys combine with and deposit in. This area is the main route to and from other gulf countries and many other important Saudi cities. Although Al-kharj economy was based on agriculture, there was a great degree of urbanization during the past few years and hence the increase of industrial areas and the increase in the diversity of communities' culture and different lifestyles. Al-kharj lies at 24° 8′ 54″ N 47° 18′ 18″ E, and is composed of several towns. There exists a great variety on dwelling styles, depending on the economical and social level of the populations. The traditional mud building is old and, in general, poorly ventilated, in contrast, cemented building is well ventilated and constructed of concrete, cement, bricks and blocks.

A total of about 100 different dwellings in Al-kharj city are targeted in this survey classified as schools, homes, hospitals and working places. In each dwelling, more 3 different places are subjected to radon and equilibrium factor measurements.

2.2. *Radon monitoring device*

Passive device was employed in this survey to measure the time-integrated radon concentration. CR-39 detector is widely used passive device in radon survey because it is suitable for accumulating the results over long periods extend to one season (3 months). CR-39 detectors are exposed to radon in two different configurations, Can- and Bare-mode configurations.

2.2.1. *Can-mode configurations*

A diffusion cup of 5.5 cm diameter and 8 cm high is fitted with CR-39 detector (Intercast, Italy; 700 μm thick). The sensitive chamber volume, which is the air volume above the detector, is about 190 ml. The cup is equipped with a filter paper with a thickness of about 0.35 mm and a diameter of 70 mm. The filter is protected against any damages by a filter support. The filtered detector recording alpha particles from radon and the equilibrium daughters inside the cup and then can be calibrated for radon measurement.

2.2.2. *Bare-mode configurations*

A bare detector is mounted outside the cup to record alpha particles from radon as well as radon daughter and will be used for the equilibrium factor determination.

2.3. *Experimental method*

The diffusion cups as well as the bare detectors were placed on the ground floor at a height of 2 m (so that the detectors are not disturbed by the movement of the residents) and about 1 m below the ceiling of the room so that direct alpha particles from the building material of the ceiling do not reach the detectors. For schools, the detectors were exposed in the area of the main activities in the studied dwellings like classrooms, staff rooms, science labs, and activities in the schools, waiting rooms, clinics, files rooms and intensive care units in hospitals, living rooms, bedrooms, kitchens and bathrooms in homes and offices and laboratories in the working places.

After the exposure period, CR-39 detectors as well as the bare detectors were collected and etched together in 6 N NaOH solution at 70 °C for 6 h (Abo-Elmagd, Metwally, Elmongy, Salama, & El-Fiki, 2006). The detectors were then washed with distilled water and dried. The alpha tracks were counted manually under an optical microscope of 400× magnification power. The correction was applied for the background alpha tracks in CR-39 plastic by subtracting the number of tracks