VARIABILITY OF RADON CONCENTRATIONS IN DIFFERENT COMPARTMENTS OF DWELLINGS IN EGYPT

HAYAM A. ABDEL GHANY*

SUMMARY: Inhalation of indoor radon has been recognized as one of the health hazards. Building materials, natural gas and underground-derived water supply are considered the major sources of indoor radon and its daughters. In this work a set of radon measurements was carried out, using CR-39 solid state nuclear track detector, in different compartments of dwellings in Cairo built of the same type of building materials. The results showed that the radon concentrations and exhalation rates in these houses varied from 47.94 to 84.32 Bqm^{-3} and 2.59 to 4.04 mBqm^{-2} h^{-2} respectively. The mean values of radon concentrations in living rooms, bedrooms, bathrooms and kitchens were 50.98 ± 1.94, 53.18 ± 3.69, 79.36 ± 2.96, and 81.29 ± 1.93 Bqm^{-3}, respectively. The mean values of exhalation rates were 2.68 ± 0.11, 2.79 ± 0.19, 4.01 ± 0.18, and 4.22 ± 0.12 mBqm^{-2} h^{-1}, respectively. This data show that bathrooms and kitchens have significantly higher radon concentrations and exhalation rates compared with other compartments and the outdoor levels.

Key Words: Radon exhalation, building materials, track detector.

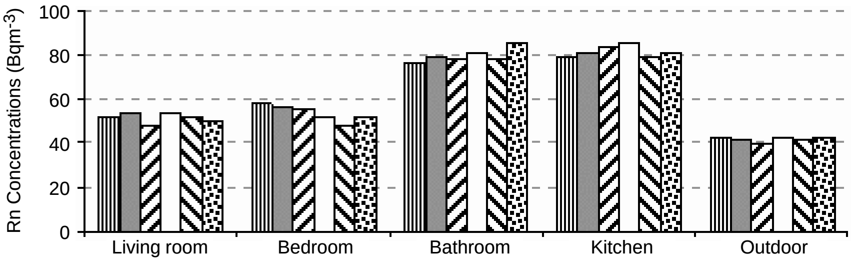
INTRODUCTION

Indoor air is a dominant exposure for humans, where more than half of the body's intake during a lifetime is air inhaled in the home. Thus, most illnesses related to environmental exposures stem from indoor air exposure (1). All building materials that originate from minerals may contain amounts of radionuclides such as uranium and thorium, which are created from their radioactive decay chains. Of these, the most significant is radium (Ra-226). Presence of Ra-226 in building materials affects persons living in dwellings either by inhalation of radon daughters, that decay from radium and are released from the building materials to the indoor air, or by hard gamma radiation released from the building material as a consequence of the radioactive decay of the natural radionuclides (2). In addition to the building materials, the natural gas used domestically (3) and the underground-derived water supply (4) are potential sources of indoor radon and its daughters.

*From Faculty of Girls for Art, Science and Education, Ain-Shams University, Cairo, Egypt.

The health hazards associated with radon inhalation may be significantly greater in buildings with boor ventilation. In the traditional building style in Egypt, kitchens and bathrooms, rather than other compartments in the same dwelling are, exclusively supplied with natural gas and water supplies and less ventilated. Also, some building materials, such as ceramic are used extensively in these compartments. This triggers our interest to evaluate both radon concentrations and exhalation rate in different compartments in dwellings having a similar building style and located in the same neighborhood in Cairo city by using solid state nuclear track detector (SSNTD).

Figure 1: Radon concentrations (A) and exhalation rates (B) in different compartments.



(A)

(B)

MATERIALS AND METHODS

This study includes indoor radon measurements in different compartments (living room, bedroom, bathroom and kitchen) of 6 houses. All apartments investigated are located in the same floor number (4th floor) in apartment complexes constructed, simultaneously and located in the same district at Cairo city. Also, all apartments have the same architectural design and finishing style, where both the bathrooms and kitchens walls are covered with different brands of ceramic, whereas walls of bedrooms and living rooms are painted with regular painting materials and polyvinyl chloride (PVC) floors. The CR-39 nuclear track detector (TASTRA™, manufactured by Track Analysis Systems Ltd. HH Wills Physics laboratory. Birstol, BS8 ITL) was used in this work. The detector was fragmented into squares (1X1 cm), lightly cleaned with absolute alcohol and then mounted in cans as previously described (5). Ninety CR-39-containing cans were used in triplets. Five sets (15 cans) were placed in the living room, bedroom, kitchen, bathroom and the balcony (as an outdoor control) of each house. After one month exposure, cans were collected, detectors were removed and then etched in 6.25N NaOH solution at 70°C for 3 hours. The track density was determined microscopically. To determine radon concentration, the number of tracks (N), exposure time (t), the background (N_B), area of view (S), calibration factor k = 0.18 α-tracks cm^{-2} d^{-1} per Bqm^{-3} of radon and number of fields (M) have been applied to equation number 1 (6). The exhalation rate (E) was computed as previously described (5,7), where radon concentration (C) in Bqm^{-3}, effective volume of the can V in m^3, λ the decay constant for radon in h^{-1}, exposure time (T) in hr and area of the can in m^2 were applied to equation number 2.

$$C = \frac{N - N_B}{k\,S\,t\,M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$E = \frac{C\,V\,\lambda}{A\left[T + 1/\lambda\left(e^{-\lambda T} - 1\right)\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

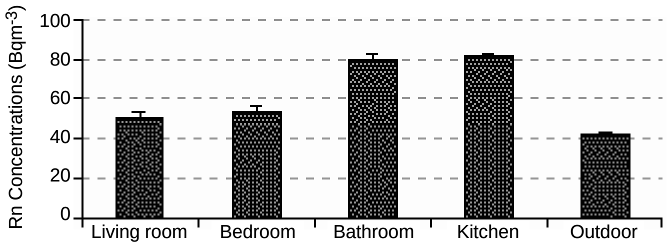
The annual effective dose equivalent is computed from the integrated radon concentration using the following formula:

$$D = \frac{\left(R \times 0.4 \times 3.88\,mSv\,WL_M^{-1} \times 7000\,h\right)}{\left(3700\,Bqm^{-3} \times 170\,h\right)}$$

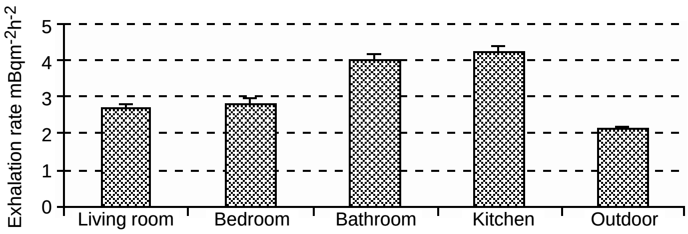
Where, D is the annual effective dose equivalent in $mSvy^{-1}$.
R is the integrated radon concentration in Bqm^{-3}.
0.4 is the equilibrium factor.
3.88 mSv WLM^{-1} is the ICRP conversion factor.

The other factor to be accounted for is the house occupancy factor (8).

Figure 2: The mean values of radon concentrations (A) and exhalation rates (B) in different compartments (p<0.05 considered significant).



(A)



(B)

RESULTS AND DISCUSSION

According to the assessment made by the UNSCEAR-2000, radon and its progeny on average accounts for about half of all human exposure to radiation from natural sources (9). The inhaled radon progeny pass from lungs into the blood and body tissues and may indicate many types of soft tissue cancers such as lung cancer, kidney cancer and prostatic cancer as well as leukemia, melanoma and child cancers (10,11).

Building materials are a potential source of radon. Due to its hazardous effect on the health of man, many reports have investigated the indoor radon concentration (12). Considering the difference in the design and finishing materials used indoor, we thought to further investigate radon concentration in different compartments within the same apartments, particularly the ventilation and finishing building materials may vary from one compartment to another. Radon concentration was measured using triplets of CR-39-containing cans during Spring period. Figure 1 shows the values of radon concentrations and exhalation rates in different compartments (living room, bedroom, bathroom and kitchen) of 6 different apartments. The radon concentrations recorded range from 47.94 to 84.32 Bqm^{-3} (Figure 1a), whereas the exhalation rates range from 2.50 to 4.4 $mBqm^{-2}$ h^{-1} (Figure 1b). A significant variability, in both radon concentrations and exhalation rates, were observed among different compartments ($p<0.0001$). Compared to the outdoor values all indoor compartments showed a significantly higher radon concentration ($p<0.0001$) and exhalation rate. The mean values of radon concentrations in living rooms, bedrooms, bathrooms and kitchens were: 50.98±1.94, 53.18±3.69, 79.36±2.96, and 81.29±1.93, Bqm^{-3}, respectively (Figure 2a). The mean values of exhalation rates were 2.68±0.11, 2.79±0.19, 4.01±0.18, and 4.22±0.12, $mBqm^{-2}$ h^{-1}, respectively (Figure 2b).

Also, the results indicate that radon concentrations in some compartments like kitchens and bathrooms, in all apartments we investigated, were significantly higher ($p<0.0001$) than the radon concentrations measured in living rooms and bedrooms, whereas no significant difference was observed between kitchens versus bathrooms ($p=0.25$) and bedrooms versus kitchens ($p=0.21$). Although kitchens and bathrooms are constructed mainly from the same skeletal building materials (concrete and cement blocks), the finishing materials used in such compartments, largely differ from that used in other locations within the same apartment. Ceramic, in particular is used extensively to replace the traditional painting materials, commonly used in living and bedrooms (12). Previous reports have indicated that ceramic is a potential source of radon, from where radon is mainly emerging from the decay of thorium and uranium in these materials (13). Another factor explain-

Table 1: Annual effective dose equivalent due to radon and its daughters.

Compartments	House						
	1	2	3	4	5	6	Mean ± S.D.
Living room	0.88	0.91	0.82	0.91	0.88	0.85	0.88 ± 0.036
Bedroom	0.99	0.97	0.94	0.88	0.82	0.88	0.92 ± 0.069
Bathroom	1.31	1.37	1.34	1.39	1.34	1.45	1.35 ± 0.030
Kitchen	1.37	1.39	1.42	1.45	1.37	1.39	1.4 ± 0.034

ing the high levels of radon and exhalation rates in these compartments, are the boor ventilation status due to the relatively narrow openings. Using natural gas in houses (14) and supplying kitchens and bathrooms with water originated from underground sources are considered as a potential source for indoor radon (15). Here we exclude the water-derived radon as the houses we investigated were supplied with Nile water. Also, we computed the annual effective dose equivalent from the corresponding measured radon concentrations (Table 1). The data show that the annual effective doses in both bathrooms and kitchens are higher than that in both living rooms and bedrooms.

CONCLUSION

This work reports that kitchens and bathrooms have relatively high their radon content compared to other compartments of the same dwelling. It is suggested that improvement of ventilation in such compartments is easily possible by simply reducing radon content of their ambient air.

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Correspondence:
Hayam Ahmed Abdel Ghany,
Faculty of Girls for Art,
Science and Education,
Ain-Shams University,
Cairo, EGYPT.
e-mail: Hayam168@maktoob.com