Exposure of school children to alpha particles

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Background: A substantial part of the public's natural radiation dose is due to the inhalation of radon gas. Most of the exposure occurs indoors where the airborne concentration of radon and its decay products is usually higher than outdoors. *Materials and Methods:* Radon activity concentration has been measured twice in 50 classrooms in 5 levels (10 each) during summer and winter using solid-state nuclear track detectors (CR-39). *Results:* The indoor radon levels in the classrooms were slightly higher than exclusion limits recommended by the ICRP in the first and second floors and fill within the safe limits in the higher floors, where the average radon concentrations were found to be 57.6 ± 3.33, 48.5±3.10, 34.5 ± 1.71, 29.7 ± 1.33 and 25.3 ± 1.88 Bq/m^3 for first, second, third, fourth and fifth floors with good ventilation, respectively; and 78 ± 3.23, 66.9 ± 2.84, 40.3 ± 1.70, 34.4 ± 1.42 and 28.8 ± 1.75 Bq/m^3 for classes with poor ventilation respectively. The mean annual radiation doses obtained on inhalation exposure to Rn-222 and its degradation products were 0.85 ± 0.37 and 0.67 ± 0.23 mSvy^{-1} for classes with closed and open windows, respectively. *Conclusion:* From the results obtained it can be concluded that values of radon and its daughter products and the resulting dose in the classrooms fill within the safe limit. Poor ventilation, construction materials, and radon exhalation from the ground are the main reasons for the relatively high radon concentrations in the lower levels. **Iran. J. Radiat. Res., 2008; 6 (3): 113-120**

Keywords: *Radon, school, CR-39 solid state detector, radiation doses, ventilation.*

INTRODUCTION

Radon is recognized as a public health concern for indoor exposure. The dangers to the human health upon exposure to radon and its daughter products is the main motivation behind the vast number of studies performed to find the concentration of radon in different living environments, including school. The presence of radon and its daughter products in schools are due to various sources including building materials and soil under the school buildings. Many factors affect radon concentration in schools, the elevation above ground level, ventilation and building materials. In previous work radon concentrations was reported to be higher in rooms in first floor than that above (1). Schools may be a significant source of radon exposure for children and working staff. However, because occupancy patterns in schools differ from those in homes, the actual exposures received by each individual, or even by the entire school population, are difficult to determine. In previous report (2), measured the radon concentration in 25 classrooms, and he found that the level of radon and hence alpha dose equivalent rate have increased with the floor number. Children, teachers and other school employees may spend most of their time in one room or may visit several classrooms each day. Each of these rooms may have different average radon concentrations (3).

Most of the data relating lung cancer to radiation exposure during childhood comes from studies on Japanese atomic bomb survivors. These data suggested that children may be more susceptible than adults to cancers induced by radiation for two reasons. First, children have smaller lung volumes and higher breathing rates, which may result in higher radiation doses to children from a given radon concentration. Second, based upon data currently available, it appears that the probability that the ability of specific dose of radiation to induce cancer may decrease with the age of the exposed subjects (4).

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MATERIALS AND METHODS

One hundred CR-39 radon detectors were distributed in 10 classrooms in 5 levels chosen randomly in elementary school in Cairo. The measurements were performed for a period of three months each in summer in classrooms with open windows and in winter in the same classes with closed window. The structure of passive dosimeters has been described else where by several workers [5]. The dosimeter used in this study consisted of plastic cup and detector (CR-39 Polyallyl diglycol carbonate, Intercast, Italy) nuclear track detector with 500 µm thickness and with dimensions of 1cm × 1cm. Detectors were mounted in a flat position at the bottom of a plastic cup and were held in place by a small piece of glue-tape, as shown in figure 1. The plastic cup has dimensions of 70 mm diameter orifice, 50 mm diameter base and 65 mm depth. The top of the each cup was completely covered with permeable film (polyethylene foil) to allow only ^{222}Rn gas to pass through the filter and to exclude the nongaseous radon daughters from entering the dosimeter [6].

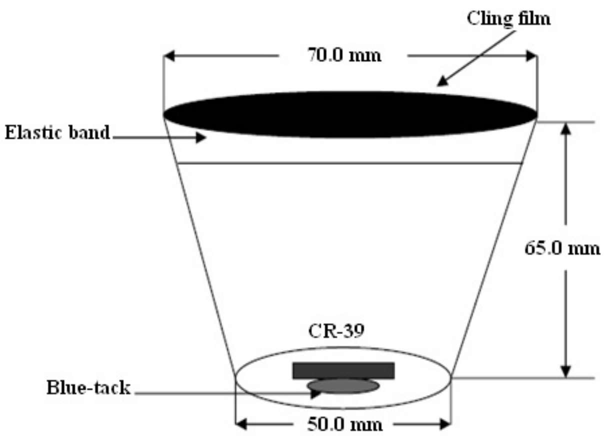

Figure 1. Typical CR-39 dosimeter.

All dosimeters were fixed in different classrooms and left for exactly three months during summer and winter times. After this period, the dosimeters were collected where the detectors were taken out then chemically etched in 6.25 N-solution of NaOH at a temperature of 70 °C for six hours. During the etching process, the solution was, constantly stirred. Detectors were then washed with distilled water and drained prior to microscopic inspection. An optical microscope (400× magnification) was used to count the number of tracks per cm^2 on each detector. The track density was converted into radon concentration in Bq/m^3 using the calibration factor. The calibration of CR-39 should be performed where the integrating radon's concentration is known [7].

RESULTS

The decay products of radon-222 are rarely in equilibrium with the parent gas. The concept of equilibrium factor has therefore been introduced. The equilibrium factor, F, is defined as that concentration of radon-222, which, is in equilibrium with its short-lived decay products [8]. Radon-222 decay products are generally given in terms of a C_{Rnp} and estimated by multiplying an equilibrium factor F between radon and its daughters to radon concentrations as follows:

$$C_{Rnp} = F\, C_{Rn}$$

These Radon-222 daughters concentrations were calculated under assuming 7000 hours [9] per year indoors or 2000 hours per year [10] at work and F=0.4. Accordingly, the indoor C_{Rnp} is derived using above equation.

Figure 2 shows the histograms of the average radon and radon progeny concentrations measured in different classrooms in different floors, with good and poor ventilation (during open and closed windows). The concentrations were determined according to the equation given by Tanner (1978) [11] in which: $C_{Rn} = (N - B)t/ C_F$, where, C_{Rn} is the mean Rn-222 concentration (in Bqm^{-3}), "N" is the track density (in T.cm^{-2}), "B" is the back ground track density (in Tcm^{-2}), C_F is the calibration factor in terms of α-tracks.cm^{-2}d^{-1}per Bqm^{-3} and t is the exposure time (in hours).

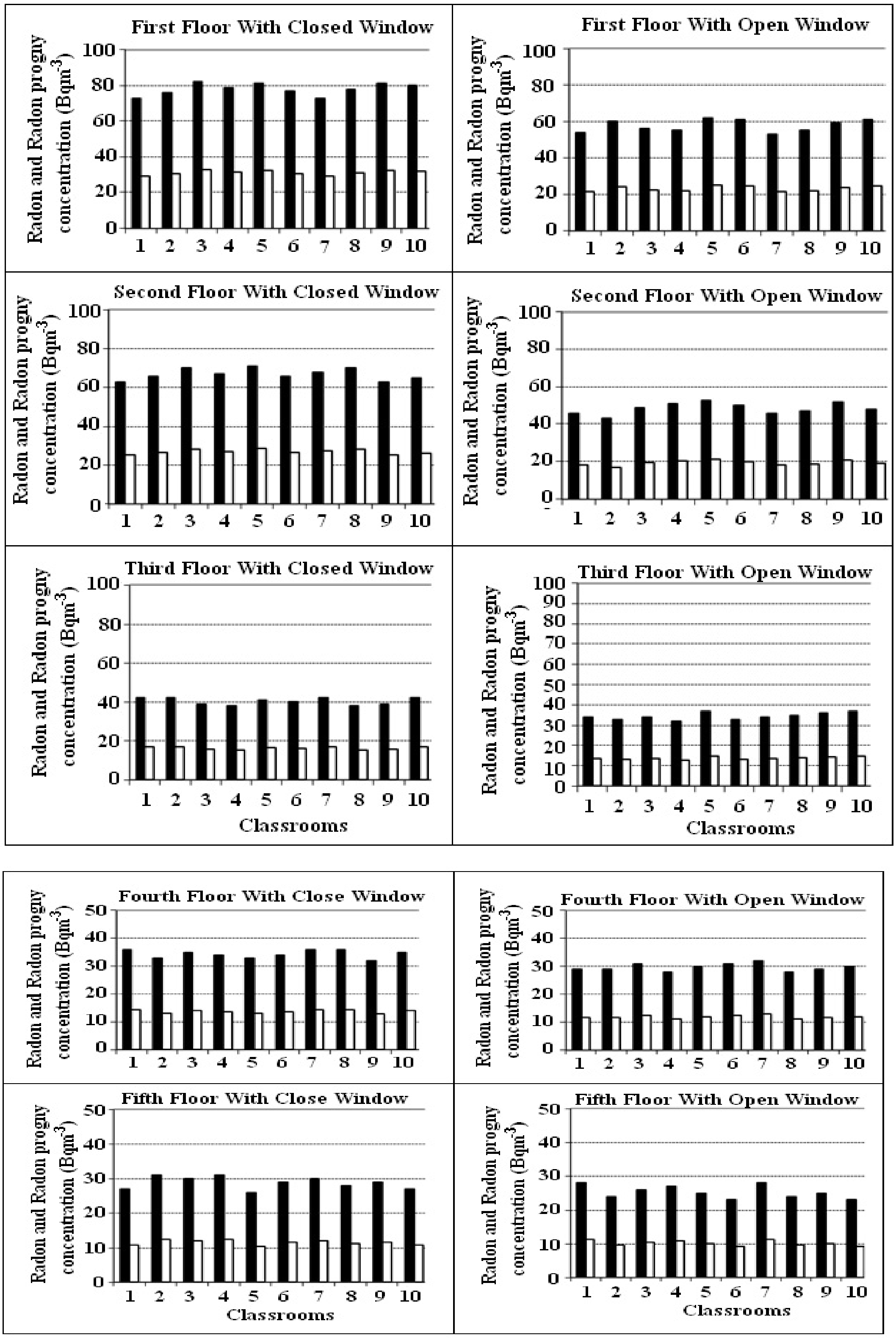

Figure 2. Radon (■) and radon progeny (□) concentrations in first– fifth floors with closed and open windows.

The minimum, maximum and average radon and its progeny concentrations obtained at different classrooms (with closed and open windows) are given in tables 1 and 2. It was found that in classrooms in the first floor, the radon and its progeny concentrations ranged from 73 to 82 Bq/m^3 and from 29.2 to 32.8 Bq/m^3 with closed window, respectively, while the concentrations of radon and its progeny in first floor ranged from 53 to 61 Bq/m^3 and from 21.2 to 24.4 Bq/m^3 with open window, respectively. In classrooms located in the second floor, the radon and its progeny concentrations ranged from 63 to 71 Bq/m^3 and 25.2 to 28.4 Bq/m^3 with closed window, respectively and from 43 to 53 Bq/m^3 and from 17.2 to 21.2 Bq/m^3 with open window, respectively. In classes rooms of the third floor the radon and its progeny concentrations ranged from 38 to 42 Bq/m^3 and from 15.2 to 16.8 Bq/m^3 with closed window, respectively and from 32 to 37 Bq/m^3 and from 13.6 to 14.8 Bq/m^3 with open window, respectively. In the fourth floor the radon and its progeny concentrations ranged from 33 to 36 Bq/m^3 and from 13.2 to 14.4 Bq/m^3 with closed window, respectively and from 28 to 32 Bq/m^3 and from 11.2 to 12.8 Bq/m^3 with open window, respectively. In the fifth floor the radon and its progeny concentrations ranged from 26 to 31 Bq/m^3 and from 10.4 to 12.4 Bq/m^3 with closed window, respectively and from 23 to 28 Bq/m^3 and from 9.2 to 11.2 Bq/m^3 with open window, respectively. Thus, the average radon concentrations were found to be 57.6 ± 3.33, 48.5 ± 3.10, 34.5 ± 1.71, 29.7 ± 1.33 and 25.3 ± 1.88 Bq/m^3 for first, second, third, fourth and fifth floors with open windows, respectively and 78 ± 3.23 , 66.9 ± 2.84, 40.3 ± 1.70, 34.4 ± 1.42 and 28.8 ± 1.75 Bq/m^3 for first, second, third, fourth and fifth floors with closed windows, respectively. As the data shows that the indoor radon was influenced mainly by the ventilation condition of the classrooms. The ventilation rate recorded a maximum values in summer and minimum values in winter. But unusual variation was observed mainly in classrooms, which remained closed for a long time during the summer vacation. Also, increase or decrease of radon concentrations depending on the type of ventilation system and the construction of the school.

Table 1. Minimum, maximum and average values of radon and radon progeny concentrations (Bq/m^3) at the studied classrooms with closed window.

	Rn Concentrations			**Rnp Concentrations**		
Floor No.	**Min.**	**Max.**	**Average ± S.D.**	**Min.**	**Max.**	**Average ± S.D.**
First	73	82	78±3.23	29.2	32.8	31.2±1.80
Second	63	71	66.9±2.84	25.2	28.4	26.76±1.54
Third	38	42	40.3±1.70	15.2	16.8	16.12±0.93
Fourth	33	36	34.4±1.42	13.2	14.4	13.76±0.79
Fifth	26	31	28.8±1.75	10.4	12.4	11.52±0.66

Table 2. Minimum, maximum and average values of radon and radon progeny concentrations (Bq/m^3) at the studied classrooms with open window.

	Rn Concentrations			**Rnp Concentrations**		
Floor No.	**Min.**	**Max.**	**Average ± S.D.**	**Min.**	**Max.**	**Average ± S.D.**
First	53	61	57.6±3.33	21.2	24.4	23.04±1.33
Second	43	53	48.5±3.10	17.2	21.2	19.40±1.12
Third	32	37	34.5±1.71	13.6	14.8	13.80±0.79
Fourth	28	32	29.7±1.33	11.2	12.8	11.88±0.68
Fifth	23	28	25.3±1.88	9.2	11.2	10.12±0.58

Additional findings reported by other investigators in schools [12, 13] demonstrated that radon concentrations in schools typically vary from room to room, and schools in the same general area can have significantly different radon concentrations. Our previous study [14] predicted a similar variability in radon concentrations in different compartments of the same house. In contrast the results we obtained did not show such significant differences between classrooms located in the same floor and the changes was more obvious between the lower and the most upper floors this may be explained by the similarity in classroom areas and construction. Also, variation of radon concentrations over time as reposted by Alberto *et al.* (1997) [15], was not seen in this work, where this factor (time) was kept constant during summer and winter measurements. Compared to the data, previously we obtained in houses in Cairo city the radon concentrations varied from 47.94 Bqm^{-3} to 84.32 Bqm^{-3}. While the measurements in the schools varied from 23 Bqm^{-3} to 82 Bqm^{-3}. The variability found in schools may be similar that found in houses. Similar to other studies carried out on residential houses, radon concentrations were considerably higher in basement and first floor rooms than on upper level floors [16]. This reflects the soil as a main source of radon that escape to the buildings. Figures 3 and 4 shows decrease in the radon and radon progeny concentrations with floor number. This could be due to the reduced effect of radon exhalations from the ground. Comparing the school results with that of houses, we found that the average values of radon level concentrations in school are lower than that of the dwellings. This mainly due to the fact that schools were painted and well ventilated [17].

The results obtained in this work were quite similar to those reported by other investigator [15], where higher radon-222 levels were recorded in houses having poor ventilation. This confirms the importance of ventilation in order to avoid the accumulation of radon to an extent that might exceed the recommended international action level. Furthermore, higher radon levels were also recorded in some houses having unfinished walls and floors [18]. This stresses the importance of room finishing in decreasing radon concentrations levels. In the same context, previously we demonstrated the effect of building materials on the indoor radon level [14].

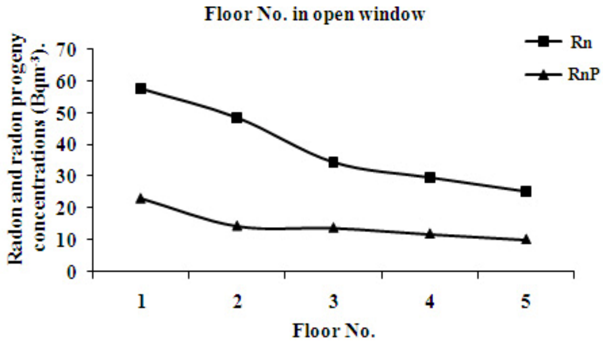

Figure 3. Radon concentrations in different highest with open window.

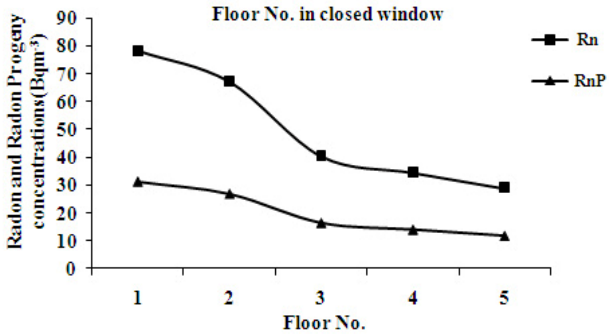

Figure 4. Radon concentrations in different highest with closed window.

Figures 5 and 6 shows the variability of annual effective dose with floor numbers in closed and open windows, respectively which was computed from the integrated radon concentration using the following formula:

$$D = \frac{R \times 0.4 \times 3.88\,\text{mSv}\cdot\text{WLM}^{-1} \times 7000\,\text{h}}{3700\,\text{Bqm}^{-3} \times 170\,\text{h}}$$

Where, D is the annual effective dose equivalent in $mSvy^{-1}$; R is the integrated radon concentration in $Bq\cdot m^{-3}$; 0.4 is the equilibrium factor; 3.88 mSv·WLM is the ICRP conversion factor. The other factors are to take account of the house occupancy factor [19].

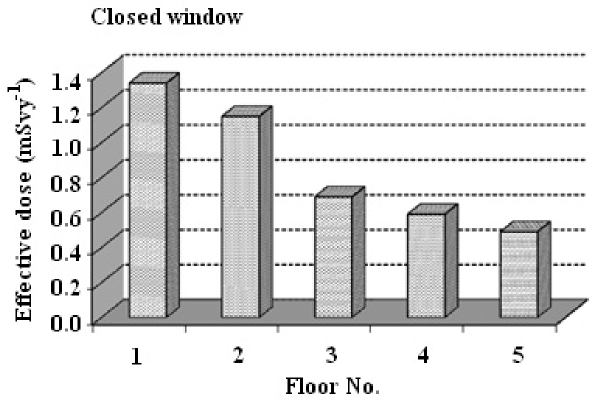

Figure 5. Effective dose in different floors with closed window.

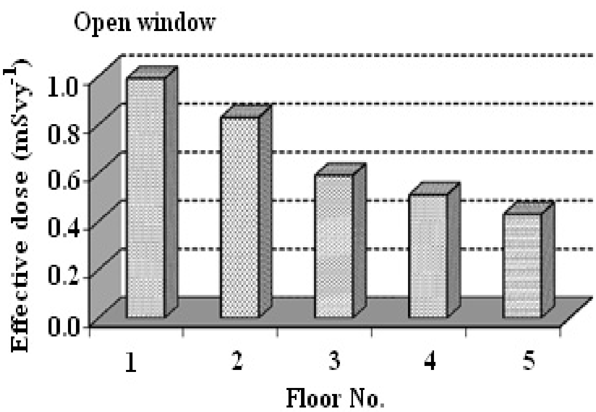

Figure 6. Effective dose in different floors with open window.

In general, indoor radon concentration is subject to seasonal variability. The reasons may be attributed to some meteorological influences on the transport properties of soil, such as temperature, frozen soil layers and soil water saturation. Also, the living habits, such as the tendency to open windows in summer and to keep them closed in winter. This leads to higher accumulation of radon and annual effective dose, particularly in closed rooms in winter [20] The mean annual radiation doses obtained on inhalation exposure to Rn-222 and its degradation products were 0.85 ± 0.37 and 0.67 ± 0.23mSvy^{-1} for closed and open windows, respectively.

CONCLUTIONS

It may be concluded that the observed values of radon and daughter products and the resulting dose in the classrooms fill within the safe limit as prescribed by [19], particularly in the higher floors with good ventilation. The work also focuses on modifying parameters that may affect indoor radon concentration levels such as floor number of the classrooms and ventilation rate. Also, poor ventilation, construction materials, and radon exhalation from the ground are the main reasons for the relatively high radon concentrations in the lower levels. Improving ventilation of low level classrooms resulting in increasing air exchange rates with outside will largely lower the radon concentrations. The significance of such studies is to monitor the radon level as a risk factor for lung cancer.

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