Technical Report

Preliminary Survey of ^{222}Rn Concentration in Cairo Homes[†]

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Results of a survey of ^{222}Rn concentration using direct measurement in 834 Cairo houses are reported. Although the study was not random with respect to population or land area, it was useful in identifying areas at risk and locating several houses having elevated indoor ^{222}Rn air concentrations. Approximately 22% of the houses tested exceeded 37 Bq/m³, with 2.4% exceeding 70 Bq/m³. Several Cairo regions had larger fractions of houses exceeding 49 Bq/m³, such as Madinat Al-Muquattam (44%), Manshiyyat Nasir (31%), Al-Abbasiyyah (29%) and Hadiak Al-Qubbah (17%). Elevated ^{222}Rn concentrations were measured for a variety of house types having different construction materials. The effect of water was identified as a potentially significant source of ^{222}Rn in Madinat Al-Muquattam homes. This survey is the first by this method in Egypt (a hot region). The indoor concentration of ^{222}Rn were measured in homes, in different locations within the flat, also the concentration of radon has been shown to decrease with the increase of the distance of room investigated from ground level with different heights in a tall building during the winter and summer seasons. Indoor radon concentration ranged from 6.32 Bq/m³ to 97.68 Bq/m³ and averaged value with standard deviation was 21.77 ± 7.85 Bq/m³. The concentrations of radon in the unoccupied flats were observed to be considerably higher than those occupied one.

Key Words : radon-222, indoor radon concentration, scintillation cell, survey, Egypt

1. Introduction

Radon (^{222}Rn) enters the human environment through the mechanism of diffusion and transport through the earth's crust. Many factors control emanations and migration of radon, including the geology and the tectonics of the area. In addition to soil, radon is also released from building materials.

In living homes it can reach values that are considerably higher than the outdoor concentration. Radon and its decay products contribute more than half of the total natural environ-

mental ionizing radiation dose to the world population¹⁾.

In view of its health hazard, radon is now being monitored all over the world. Unfortunately, there is no national survey of radon levels in dwellings in Egypt. There are, however, some limited studies in places of special interests^{2) - 5)}. Several surveys have been performed in the past few years in different countries in Europe, Asia and North America^{6) - 14)}. It was, therefore, important to shed light on the radon levels in local buildings, since the life style and building use are affecting the indoor radon level. This study aims to acquire some basic information about the range of radon concentration in multi-story residential buildings, and to check for buildings with particularly high radon levels

[†] カイロにおける住宅内の ^{222}Rn 濃度についての予備的調査。Tarek ELNIMR : Tanta 大学理学部物理学科放射分析研究室

Fig.1 Map of Cairo showing counties.

Fig.2 Original map of Cairo.

and possible variation in various areas in Cairo. This result should be considered as guidelines for more comprehensive studies. It should not be taken to represent the mean ^{222}Rn concentration in Egyptian homes.

2. Area

Cairo is the largest population city in Egypt. Cairo extends on the banks of the River Nile to the south of its delta. It has an area of 457 km² (0.04% of the national area) and is at present inhabited by about 9 million people (~13% of the Egyptian population). It has 23 districts.

Figure 1 shows the map of Cairo and its districts in which these measurements were done, and Figure 2 shows the bird's-eye view of Cairo.

3. Selection of Dwellings

The selection of buildings was generally random depending only on the permission from the volunteers. It was hard to get the permission from the residents to carry out the measurements particularly because no authority was behind this study. Therefore, the selection of buildings and flats was mainly based on the existence of direct or indirect relation with the residents. Care was given to collect an adequate number of samples in each district included in the study (18 districts). No working places are included in this study. Most Egyptian flats have moderate ventilation because windows are generally not tight which provide continuous air exchange. The fact that the temperature is not very low even in winter had led to no needs to construct air-tight windows. Only recently some buildings have been characterized by forced ventilation systems and air-tight windows. Such buildings were not included in this study.

Fig.3 Figure of the cell.

4. Materials and Methods

In 2000 – 2001' a series of measurements of indoor radon concentrations was performed in 834 houses (private dwellings) [dining room, bathroom, kitchen, bedroom, living room and hall] in Cairo, Egypt. The total data set consisted of 2 502 samples. The main characteristics of each flat and the weather condition during measurements were recorded.

The measurements were carried out using scintillation cell; this cell has an alpha sensitive scintillator lining the inside of the cell (Figure 3). This scintillator is silver activated zinc sulfide. In order to measure radon gas, the measuring system's response to radon gas must be known. Therefore, there is a direct relationship between the number of light pulses counted by the cell and the concentration (or activity) of radon gas in the cell. This relationship is referred to as counting efficiency for a grab sample and as sensitivity for continuous sampling. Whereas, counting efficiency and sensitivity must be known before measurements can be made.

Efficiency and sensitivity can be calculated by running the cell system with a precisely known concentration of radon gas and using the following formula :

$$S \text{ or } E = (\text{net counts of light pulses/min}) / (\text{known concentration of Rn})$$

where "net counts of light pulses/min" is the total number of pulses counted by the system minus the number of counts due to background, expressed as the number of counts per minute and "known concentration of Rn" is precisely known concentration of radon gas. Efficiency or sensitivity should normally be determined every six months as part of calibration.

The specifications are as follows :

volume	$225\,000 \pm 3 \text{ mm}^3$
active area	$19\,534.7 \text{ mm}^2$
counting efficiency	$0.47 \text{ cps}/(\text{Bq}/\text{m}^3)$
background (max)	1 cpm
inside diameter	55 mm
outside diameter	58 mm

This was exposed in houses for the optimal period, in order to minimize the contributions of pretest house conditions, also corrections for humidity was done. Open windows and the use of exhaust fans during the measurement period were not preferential. Homeowners were instructed to place the instrument on a table away from air conditioners or heater vents at least 20 cm from other objects.

The locations of houses, dates and times when the instrument was opened and closed, average room temperature, and information about house construction have been recorded. Special investigations of unusual data points, such as instruments testing below $7 \text{ Bq}/\text{m}^3$ or above $90 \text{ Bq}/\text{m}^3$, were made. An air sample was grabbed in the bathroom after typical closed conditions. Then a 10 min cold shower

was run, and an additional air sample was collected. Measurements were repeated after ventilating the room.

Outdoor measurement of ^{222}Rn was generally made at 3 sampling locations in each county.

5. Results and Discussion

The results at 834 houses in Cairo, Egypt are summarized according to the locations in Table 1. The minimum detectable ^{222}Rn concentration was estimated to be $1 \text{ Bq}/\text{m}^3$. This estimated minimum detectable ^{222}Rn concentration includes the effects of weather conditions such as humidity, temperature and etc. The outdoor mean value in all counties was $2.73 \text{ Bq}/\text{m}^3$ as shown in Table 1. The data are not randomly distributed with respect to either population or county. Most of the data points were voluntary-tests, whose geographical and temporal distribution may be strongly correlated with varying levels of community, a wareness and media coverage i.e. with standard of the life. In addition to the above samples, four sets of measurements were done in the following special cases : occupied and unoccupied houses.

These houses are some of the private houses and the others are built by the government, but all of them are in Madinat Al-Muqattam, whereas these sets of measurements were made, two in the summer vacation and the other two in the winter vacation when the flats were closed and unoccupied for at least two weeks preceding each set of measurements. The rooms of these flats chosen on each floor of a building, except for the basement, were identical ; i.e. having the same volume and being on the side of the building.

The results are summarized in Table 1. The overall mean levels for all counties were $22.46 \pm 1.69 \text{ Bq}/\text{m}^3$ and $41.81 \pm 2.56 \text{ Bq}/\text{m}^3$ for

Table 1 Summary of ^{222}Rn concentration in different counties in Cairo

County	No.of houses	Outdoor mean value (S.D.) Bq/m ³	Indoor concentration Bq/m ³		Min. Bq/m ³	Max. Bq/m ³
			Mean	S.D.		
Az-zamalik	31	2.0(0.10)	14.21	0.74	6.32	45.86
Al-Manyal	38	1.9(0.12)	14.86	0.74	6.98	44.75
Shubra	41	2.6(0.14)	17.39	1.12	8.11	56.91
Bulaq	48	2.2(0.12)	16.11	0.73	8.03	57.23
Hadiak Al-Qubb	42	3.0(0.14)	17.84	0.99	9.56	61.74
Ghamrah	40	3.0(0.13)	15.43	0.78	9.01	58.39
Imbabah	38	2.4(0.12)	15.08	1.01	9.33	58.11
Al-Muhandisin	38	2.2(0.14)	15.80	1.11	8.86	57.65
Ad-Duqqi	42	2.0(0.11)	14.43	0.67	8.36	56.02
Al-umraniyyah	40	3.4(0.15)	17.23	1.59	9.30	57.06
Al-Wayli	51	2.9(0.10)	18.11	0.63	8.57	57.03
Al-Abbasiyyah	48	3.6(0.13)	21.89	1.52	9.42	62.60
Al-Maadi	31	2.9(0.13)	26.39	1.98	10.38	61.39
As-Sayyidah Zaynab	47	3.1(0.12)	24.52	2.59	9.08	55.91
Manshiyyat Nasir	45	3.4(0.14)	36.46	2.63	14.01	69.87
Madinat Nasr	42	3.6(0.11)	27.86	7.03	10.23	56.12
Al-Jamaliyyah	38	3.5(0.13)	22.74	1.53	9.44	58.09
Madinat Al-Muqattam	134	1.5(0.14)	34.71	3.11	13.36	96.95
Occupied Houses	40	-	22.46	1.69	10.87	60.78
Unoccupied houses	40	-	41.81	2.56	24.11	97.68

occupied houses and unoccupied houses respectively.

The concentration of radon has been shown to decrease with the increase of the distance of the room investigated from the ground level^{(15), (16)}. Fifty two measurements were carried out in similar rooms on different floors in six buildings. The results for these measurements are shown in Table 2. Looking at the results in Table 2, there is no clear relation between the reduction of activity of the radon with the height of the floor above the first floor.

Table 3 shows the results of eighty four measurements carried out at different loca-

tions within a flat on similar floors at the same county. Looking at the results in Table 3, there is no clear relation between the concentration level of radon with the location within a flat. More information on the correlation between average indoor ^{222}Rn concentration for type of bricks, type of soil, amount of water in the soil, style housing, climate and life styles is needed. Information on the seasonal variations of indoor ^{222}Rn concentration is also lacking for the study in Cairo.

Some of the most significant conclusions from these results are :

- i) The unoccupied flats have considerably

Table 2 Typical results of measurements in different rooms of a building (Al-Muqattam), all the rooms were of equal size, directly above each other at unoccupied houses

Weather conditions outdoors	²²² Rn concentration Bq/m ³		Floor No.	Date
	mean	S.D.		
mean temperature 34.6 C	169.51*	8.87*	Basement	2 July
sunshines all day	28.24	3.11	1	
max. gust :27 km/h	17.39	1.23	2	
	32.85	2.39	3	
	30.62	2.40	4	

*Opened before measurements were made

Table 3 Typical results of measurement in different location in one flat (Al-Muqattam)

Location	²²² Rn concentration Bq/m ³	
	S.D.	mean
bedroom	41.67	2.81
living room	45.86	2.57
hall	45.39	2.49
dining room	43.45	2.59
kitchen	52.09	2.44
bathroom	53.15	2.51

higher ²²²Rn levels (41.81 Bq/m³) than occupied one (22.46 Bq/m³). This is, maybe, due to the continuous good ventilation i.e. the ventilation is the main cause of the differences.

- ii) There is no systematic reduction of ²²²Rn activity with height in the series of closely similar rooms. This is, maybe, due to that the activity depends mainly on the ventilation rate.
- iii) The mean value of ²²²Rn in the tall buildings is less than the mean in typical houses in

the same city. It seems clear that there is no appreciable effect due to the emission from the sub-soil to the rooms above the first floor.

- iv) It appears, therefore, that the variation of ²²²Rn with height above ground level cannot be regarded as a general characteristic of all tall buildings.
- v) The variation of ²²²Rn concentration is not only affected by season and geographic area, but it depends mainly on the country parameters (geology concerned to radon).

- vi) The lowest ^{222}Rn level was in Az-zamalik (14.21 Bq/m^3) and the highest was in Manshiyyat Nasir (36.46 Bq/m^3). This is, maybe, due to the type of soil and the water content in the soil, as well as, it could be higher at sub-floor emanation due to the high concentration of radium in the foundation of the building.
- vii) Also the outdoor ^{222}Rn level (2.73 Bq/m^3) was much lower than indoor ^{222}Rn level (21.77 Bq/m^3), whereas the concentrations of ^{222}Rn in outdoor air were measured simultaneously.

6. Dose Calculations

Despite the fact that this study is not meant to provide a real risk assessment, the indoor effective dose equivalent to the Egyptian population is calculated to serve as a base line level. The annual effective dose (E) due to the exposure of ^{222}Rn and its decay products is given by

$$E \text{ (mSv/y)} = C_{\text{Rn}} \text{ (Bq/m}^3\text{)} \cdot F \cdot t \text{ (h/y)} \cdot D_{\text{Rn}} \text{ (nSv/Bq} \cdot \text{h/m}^3\text{)} \cdot 10^{-6}$$

where C_{Rn} is the concentration of ^{222}Rn , F is the equilibrium factor between ^{222}Rn and its decay products, t is the annual time of exposure and D_{Rn} is the dose conversion factor. The assessment of the effective dose equivalent from airborne radon inside dwelling houses has been made by using the following assumptions. The equilibrium coefficient is 0.4, the time of remaining inside buildings is 7 000 h per year, the conversion coefficient is $9 \text{ nSv/h per Bq/m}^3$ ^{1), 17), 18)}. Based on the available data from 18 districts, the resulting effective dose equivalent from radon inhalation calculated from the mean activity was $0.52 \pm 0.17 \text{ mSv/y}$. The lowest doses (0.36 mSv/y) were in Az-zamalik and Ad-Duqqi districts and the highest two values were in Manshiyyat Nasir (0.92 mSv/

y) and Madinat Al-Muqattam (0.87 mSv/y).

7. Conclusions

Small-scale measurements of radon concentration within dwellings in Egypt is reported. This study did not provide any strong statistical basis to judge the influence of the types building materials and mode of construction of the buildings. On the other hand, there is some indication of the dependence of indoor radon concentration on ventilation. In the meantime, the radon levels measured in various floors suggests that an important source of indoor radon levels is soil. This limited survey supports the recommendation of testing mainly ground floor or first floor dwellings, since no significant increase of radon concentrations among the dwellings of the rest floors. The mean radon concentration from all data is 20.61 Bq/m^3 and the mean annual dose equivalent from radon was estimated to be 0.52 mSv/y . Annual effective dose for unoccupied apartments was found to be about 84% higher than the occupied one.

A large-scale nationwide residential radon survey is encouraged to assess the health risk. Some possible factors still need further study ; e.g. age of the building, differences in building materials, wall coverings and room area.

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