IUG Journal of Natural Studies
Peer-reviewed Journal of Islamic University-Gaza

ISSN 2409-4587

IUGNS
Vol 26, No 1, 2018, pp 01-09

Received on (15-02-2017) Accepted on (03-12-2017)

Evaluation of Indoor Radon-222 Concentration Levels in Rafah in Southern Part of Gaza strip, Palestine

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Abstract

Passive diffusion Radon dosimeters containing CR-39 solid state nuclear track detectors of good quality were used to measure Radon and its daughter's concentrations throughout Rafah city. Our sampling strategy was to distribute the dosimeters in houses in Rafah city (Tal El Sultan, Balad(Rafah camp) and El Genena) at different geographic parts of the region. These dosimeters were randomly distributed in bedroom, living room and kitchen. The (150) detectors were left for about three months during the period from June to August of 2016. The collected detectors were chemically etched by using NaOH of (6M) concentration at temperature 700C, then the average number of tracks/mm^2 detected at all the regions was 73.8 Bq/m3 (1.99 pCi/l).

Keywords:
CR-39 detectors; ^{222}Rn concentration levels; Dosimeter, Exposure.

1. Introduction:

The main objective of the study is to investigate the natural radiation pollution in the air of the southern part of Gaza strip(Rafah), particularly the measurements of radon concentration in air of houses. This study will provide a framework for future studies that may be needed for environmental studies point of view. It is required to find out the relationship between radon concentrations and health risks and many diseases that spreading in the country. Also, some bases for radiation protection countermeasures are recommended too. This includes action level recommendations for the existing houses and for future housing architect design. Moreover, with this study we also aim to create interest and increase public awareness about the radon hazard in the community. Radon problems have been identified in almost every state of the world. In most of the developed countries of the world, the radon problems have been taken seriously. Radon references and action levels have been set (Khan, 2005), (Khattak, 2015). When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon progeny ($Po^{218}$and Po^{214})can interact with biological tissue in the lungs leading to DNA damage. Cancer is generally thought to require the occurrence of at the least one mutation (WHO,2007).

Rn^{222} is present in the natural environment because of radioactive decay of U^{238} .For intermediate decay a product follow the decay of U^{238} and produce Rn^{226}, is the direct source of Rn^{222}.Because Rn^{222} is a gas, it can readily travel through several meters of permeable soil before decaying. **The major sources of Rn^{222} in indoor air are:** Soil gas emanations from soils and rocks, off-gassing of water born Rn^{222} into indoor air, building materials, outdoor air. Building materials generally contribute only a small percentage of indoor air Rn^{222} concentration. However, building materials may impart a greater Rn^{222} contribution when waste products from uranium mining were used to make concrete, concrete bulk. In some area with a high geologic Rn^{222} source outdoor gas concentration exceed several pci/l for short period(William, 2000).

Extensive measurements have been done in the world showing that radiation in homes increases Lung- cancer risk for general population, especially, those who spend a majority of their time at home. Here in Gaza we have no information about radiation concentrations. Where women and children under six years old (25% of the total population) spent more than 90% of their time at home (Sersawi, M.,2007). The birth rate will increase the problem in the future.

Area of study

Rafah is a Palestinian city and refugee camp in the southern Gaza Strip. It is the district capital of the Rafah Governorate, located 30 kilometers (19 mi) south of Gaza city. Rafah's population of 164.000. is overwhelmingly made up of Palestinian refugees. Rafah camp (Balad), Tall as-Sultan camp and El Genena form separate localities. See figure (1).

Rafah area is located at longitudes 34°15′34″ E , latitudes 31°17′13″ N and Elevation above sea level: 79 m = 259 ft

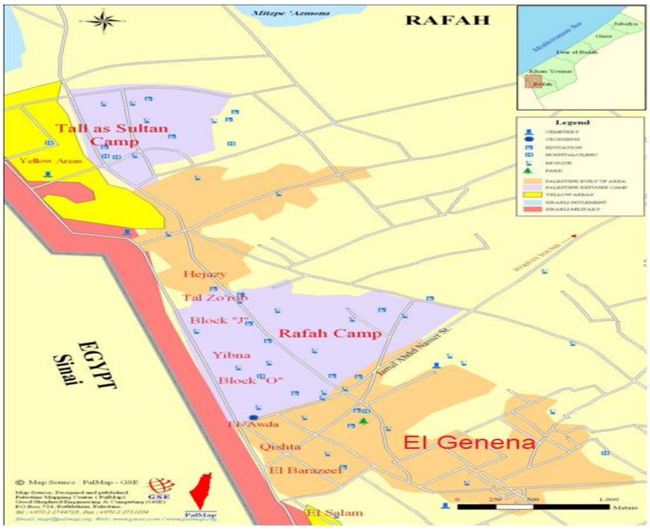

Figure (1): Map of Rafah (Palestinian National Information Centre ,2016)

Experimental Details

Our sampling strategy was to distribute the dosimeters in the buildings in the three district regions of Rafah city (Tal EL Soltan, Balad and El Genena). These dosimeters were randomly distributed in a bedroom, living room or kitchen (three dosimeters for each house). Moreover, buildings built of different material are considered in the present study like (stone and spestos) and (stone and concrete). High levels of the buildings are also taken into account, where the radon concentrations is strongly dependent. The current study is planned to determine the extent and severity of Radon problems in the locations of Rafah city. The plastic cup containing (solid state nuclear track detectors CR-39), are used for indoor radon monitoring. The detectors are cut in small pieces (usually 1cm x1cm) and fixed at the bottom of the plastic cup. The indoor radon levels have been estimated in about 50 houses (three locations) in Rafah city using integrating etched track detector. The three regions were investigated and the radon level determined. The devices are exposed to Radon for a time period of three months, after which they were collected and the CR-39 films were chemically etched using a 6M solution of NaOH, at a temperature of 700C, for about 5 hours. The detectors were then washed thoroughly with distilled water and left to dry. Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 4 distinct regions were observed; through the area (1mm^2), the average number of tracks/mm^2 was determined and analyzed. Surveys have been conducted in different types of houses in the region of study (Rafah city), houses built of different material like (stone and spostos) and (stone and concrete) which we know the Radon concentration depends, also Radon concentration depends on the height of the buildings and ventilation rate. These dosimeters were randomly distributed in a bedroom, in a living room or in kitchen.

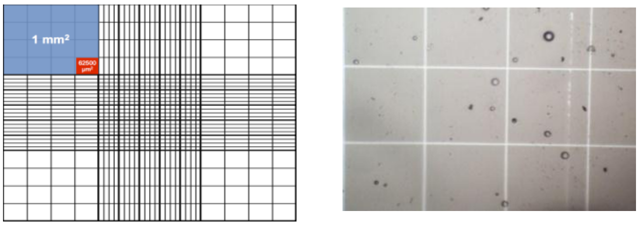

Figure 2: Tracks of alpha particles emitted by Radon in a CR-39 detector. One viewing field from the microscope has the area of about 1 mm^2 using a slide of depth 1/10 mm shown beside.

Calculations

$$C(Bq/m^3) = \frac{C_O\left(Bq.d/m^3\right)}{\rho_0}\left\{\frac{\rho}{t}\right\}_{\text{det.}} \qquad (1)$$

The Radon concentration

The solid state nuclear track detector technique is one of the most often used techniques for the measurement of Radon. Radon concentration (C) in surrounding air is measured in terms of Bq/m^3, since the most regulatory reference levels are specified in this unit. Determination of Radon and its daughter's concentrations (C) throughout Gaza Strip are carried out using the following equation (Khader,1990).

Where,

C0=the total exposure of 226Ra (Radon source) in term Bq.d/m3,

ρ 0 =track density (number of tracks/mm^2) of detectors exposed to 226Ra,

ρ =track density (number of tracks/mm^2) of distributed detectors,

t= exposure time (days) of distributed detectors.

Simply, a number of dosimeters were exposed to a known dose of 226Ra (Radon source) for a period of time. Then those dosimeters were collected and treated to chemically etching. The average numbers of tracks/m^2 were observed. These detectors were considered as a calibration standard (Khader,1990).

The calibration process that made for dosimeters used in this survey prepared and exposed to radon source, four dosimeters were exposed for 30 days of 226Ra (Radon source) of activity concentration 800 Bq/m3. It gives 572 pCi.d/L (2.12×104 Bq.d/m3) concentration for the total exposure done by Rassas (2003). in the physics laboratory, then reversed

$$C(Bq/m^3) = 8.45\times10^{-4}\left\{\frac{\rho}{t}\right\}_{\text{det.}} \qquad (2)$$

calibration constant (1/k) was found to be(8.45×10^{-4} Bq. d/track. m).Substituting by reversed calibration constant in equation (1) then,

Results and discussions

The present radon concentration levels data were obtained from150 dosimeters collected after a period of almost 3 months. The indoor radon concentrations levels were calculated using equation (2).

The main buildings ،the number of detectors, N, and the range and radon concentration levels Table 1.

Table (1): Radon concentration in each region of present study

Location	No. of detectors(N)	Ave. C(Bq/m^3)	Min. C(Bq/m^3)	Max. C(Bq/m^3)	S. D. (Bq/m^3)
Tal El Soltan	50	75.6	23.5	159.6	13.4
Balad	50	73.2	21.1	180.7	16.8
El Genena	50	72.6	16.5	169	15.1
Average value	Sum=150	73.8	20.4	169.7	15.1

Figure (3) illustrates that the average Radon concentrations of the three regions (Tal El Soltan, Rafah camp(Balad) and El Genena) are almost equivalent. The results indicate that the difference between the minimum and maximum Radon concentration in each region is very high. This large variation in this regions is mainly due to the difference in the ventilation volume, different types of these locations in building (bedroom, living room, kitchen) and height level rise of building (basement, first floor, ...etc), different materials of building like the stone and spostos, stone and concrete... etc. Some of the buildings have their windows closed all the time, most of them have the windows opened for a few hours a day. In our sample of the region, about 55% have their windows opened for more 8 hours per day. This indicates that the difference in Radon concentration is due to different ventilation in the region of study.

Other factors may also affect the Radon concentration. But, it is assumed that the main reason for concentration difference is ventilation conditions.

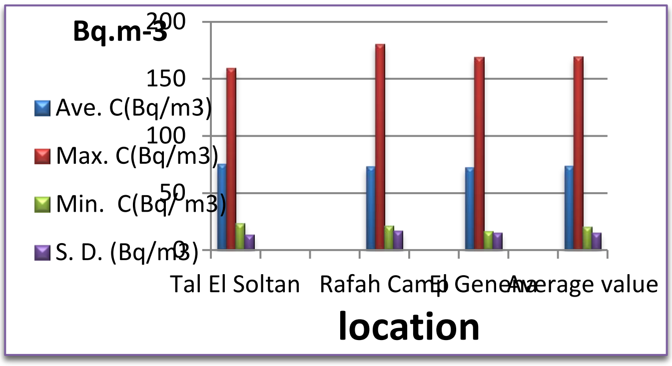

Figure (3): Radon concentration in each region of the present study.

The variation of Radon concentrations with the high level of the houses

The dosimeters have distributed in different levels of buildings that built of different materials so that the radon concentration can be detected.

Table (2): Radon concentrations variation with the level of the houses.

Location	Basement C(Bq/m^3)	1^{st} C(Bq/m^3)	2^{nd} C(Bq/m^3)	3^{rd} C(Bq/m^3)
Tal El Soltan	79 (65.4 - 86.2)	58.8 (45.3 - 63.4)	48.9 (43.1- 51.9)	47.4 (42 -50.5)
Balad	75.1 (67 -79.2)	71.1 (64.2 – 74.6)	70 (63 – 72.5)	64.1 (60 – 68.9)
El Genena	74.6 (69.2 – 80.8)	72.7 (67.2 – 78.1)	83.1 (63.2 – 87)	70.4 (59.9 - 73)
No. Of Detectors	58	47	27	15
Average	76.5	67.5	67.3	60.6

value

As shown in table (2), the Radon concentrations vary from one floor to another, and the basements are the highest Radon concentrations in all locations. This dependence demonstrates that Radon levels vary from floor to floor of the Tal El Soltan, Rafah Camp (Balad) and El Genena buildings. In these results, the Radon concentrations determined are mostly due to the contribution from the soil located under the building, and ventilation. The highest Radon concentration values were observed in the basements and decreases in the above floors due to increase in air movement.

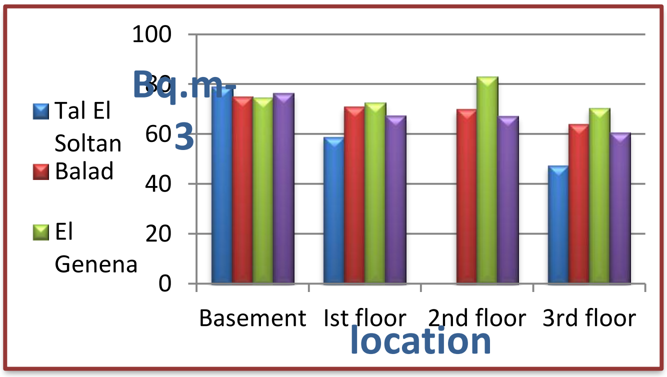

Figure (4): Radon concentrations variation with the level of the houses.

Figure (4) describes the histograms of Radon concentrations for various floors in these building locations. It can be seen that Radon levels inside the basement floors are the highest Radon concentrations in all locations. The rooms in these basement floors have small windows or less opening windows and their ventilation is poor because the building are close to each other, while rooms in the other building floors have large windows and ventilated better than in basement.

The variation of Radon concentrations with the materials of the houses

The determination of Radon concentration and its decay products in indoor air has become very important, since the main level of these measurements carried out in the different building material of detached built houses. The data describing the characteristics of the selected houses in only three regions (Tal El Soltan, Balad and El Genena) are as follows: the building are constructed of stone and spostos, and stone and concrete as shown in table (3).

Table (3): Radon concentrations versus material of house.

Location	Stone and spostos C(Bq/m^3)	Stone and concrete C(Bq/m^3)	No. of detectors
Tal El Soltan	94.1	69.8	49
Balad	85.2	56.3	44
El Genena	83.7	72.8	45
No. Of Det.	38	100	Sum(138)
Ave. value	87.7	66.3	----

The table (3) indicates that Radon concentration of the houses built of spostos and stone were 1.3 times higher than of houses built of concrete and stone in all regions.

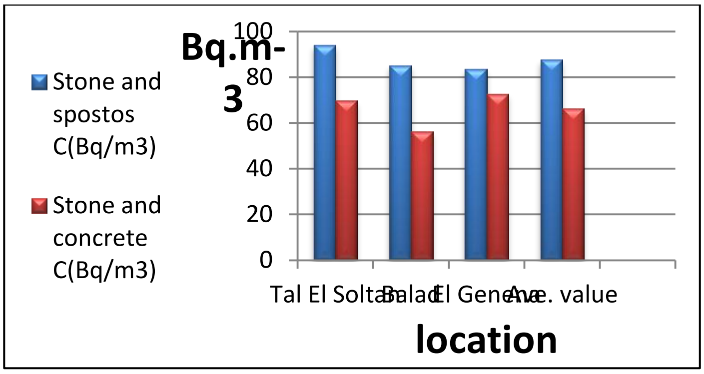

Figure (5): Radon concentration variation with materials of building of houses.

Figure (5) indicates that the higher Radon concentrations were in the houses built of stone and spostos in the three regions in comparison with the houses built of stone and concrete. Houses built of stone and concrete had low Radon concentrations in all house locations. The ventilation method in these buildings can be understood to be better than other buildings. The concentrations of Radon inside a house are varying in accordance with constructional characteristics of their foundations and by the type of ventilation system in use. Since the building materials used in the construction of detached houses are different of Radon concentration. This indicates that the different materials of houses are important parameters in determining Radon concentrations.

The variation of Radon concentrations in different rooms in the house

These results for work places (rooms) show that Radon concentrations vary from a room to another room. Although the Radon source is often concentrated in one room or in one part of the buildings, the gas streams into the other parts of the buildings, mainly because of the ventilation rate. Table (4) shows the Radon concentrations versus the different part (bedroom, living room and kitchen) of different buildings.

Table (4): Radon concentrations versus different rooms

Location	Bedroom C(Bq/m^3)	Living room C(Bq/m^3)	Kitchen C(Bq/m^3)
Tal El Soltan	77	75.4	80
Balad	71.4	65.1	79
El Genana	81.7	70.1	83.2
No. of	51	49	48
Ave. value	76.7	70.2	80.7

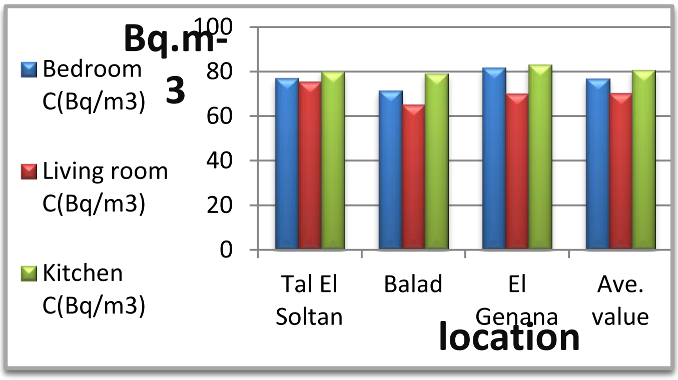

Figure (6): Radon concentrations in different rooms of the houses**.**

Figure (6) indicates that the highest Radon concentration was found in the bedroom and kitchen in most regions. While the living rooms have low Radon concentrations in most regions, and also shows Radon concentrations depending on ventilation more than on the location. This was clear from questionnaire throughout survey of the present work. One of the most important results of the previous analysis and evolutions was confirmed that Radon concentration values correlate very well with the different rooms.

The age of the building effect

There is a slight age dependency, in our study we have divided the houses to four parts: less than 10 years old, from 10-20 years old, from 20-30 years old, and from 30-40 years old.

Table (5): The age effect of the house

Location	Age of building (0-	Age of building (10-	Age of building (20-	Age of building (30-
Tal El Solt	73	69.2	83.7	89.5
Balad	65	72.1	75	91.5
Genena	56.9	75.5	86.3	83.7
No. Of	33	66	39	12
Ave.	64.9	72.3	81.6	88.2

We have seen the slight age dependency as shown in table (5). The old buildings have higher radon concentration than the newest buildings, this result equivalent to the result found by Sersawy(2007) who found radon concentration in old buildings are higher than in new buildings. This depends on the building material content in new building. However, in our region of study the difference may be due to the style of life, and high ventilation rate as well as to permanent air exchange.

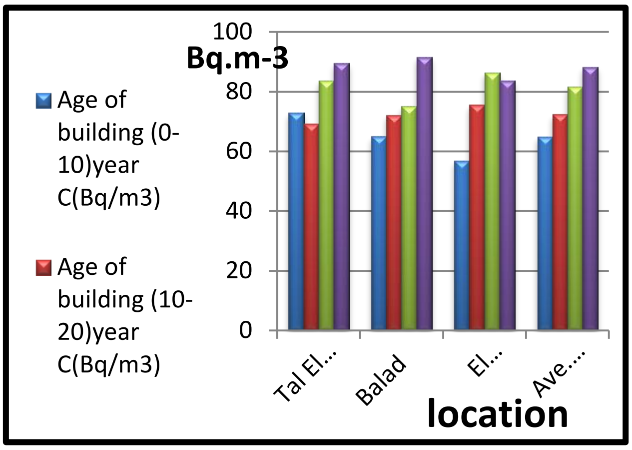

Figure (7): The age effect of the house on Radon concentration.

The ventilation rate

The important factors affect the Radon concentration are the ventilation rate and air exchange. In this work no section hasn't the ventilation as the reason of high or low Radon concentration. Therefore, we have divided the houses of study to three types of houses: bad ventilation, intermediate ventilation and good ventilation. Bad ventilation has small windows or windows left opened less than three hours a day, intermediate ventilation has left windows for three to eight hour daily and good ventilation has left windows opened more than eight hours a day. This has been observed from the questionnaire. From the results (table (6)) obtained from the area of study; It is found that Radon concentration is dependent of ventilation rate. That is in bad ventilation houses have the highest radon level is obtained and the lowest radon level in good ventilation. Thus the relation is inverse between radon level and ventilation rate. Table (6) also shows variation of radon concentrations with ventilation rate for different regions.

Table (6): Radon concentrations versus with ventilation rate.

Location	Good ventilation C(Bq/m^3)	Intermediate ventilation C(Bq/m^3)	Bad ventilation C(Bq/m^3)
Tal El So	70.3	75.4	80.8
Balad	67.3	70.8	78.6
Genena	44.6	72.8	81.4
No. of	86	15	49
Ave.	60.7	73	80.2

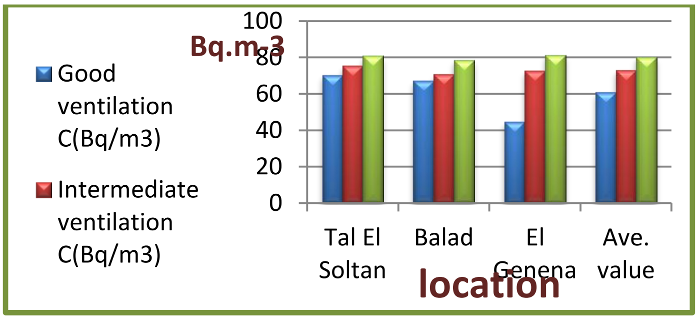

Figure (8): Radon concentrations versus with ventilation rate.

Figure (8) describes the histograms of Radon concentrations for various rates of ventilation in the buildings locations. It can be seen that Radon levels inside the bad ventilation are much higher than the Radon levels in the intermediate and good ventilation.

Conclusion

The current study is planned to determine the extent and severity of Radon problems in the locations of Rafah city. The plastic cup containing (solid state nuclear track detectors CR-39), are used for indoor radon monitoring. The detectors are cut in small pieces (usually 1cm x1cm) and fixed at the bottom of the plastic cup. The indoor radon levels have been estimated in about 50 houses (three locations) in Rafah city using integrating etched track detector. Generally, the result was found 73.6Bq/m^3 (1.99 pCi/l) with a range of values between 16.5 and 150.4.5 Bq/m^3 (0.44 and 4.06 pCi/l) and a maximum value of 180.7 Bq/m^3 (4.8 pCi/l) with average standard deviation of 15. 1,the result in Rafah city is lower than the concentration action level(148 Bq/m^3) which made by Environmental Protection Agency (EPA) and International Commission on Radiological Protection (ICRP). Despite of the limited number of detectors used in this survey, the obtained results indicate a variability in radon concentration that expected in building of Rafah city, It is found that the ventilation is the key factor that affects the radon concentration, particularly in low level rise of building rather than the higher buildings. We cannot neglect the big effect of the houses material on the radon concentration and the effect of the age of the building on the variation of the radon concentration level. This would give a wider frame work for natural radiation measurement in Gaza strip that provide data specially from environmental point of view.

Reference list

Abu Saleh, R. (2005). Measurement of Radiation in Soil in the Middle of Gaza Strip (Unpublished Master's Thesis). The Islamic University of Gaza, Palestine.

EPA (Environmental Protection Agency). (2010). A Consumer's Guide to Radon Reduction. Retrieved September,5,2010,from:www.epa.gov/radon/pdfs/consguid.pdf

Harara, S. (2007). Investigation of Radon Pollution in The Groundwater of the Southern Part Of Gaza Strip, Palestine (Unpublished Master's Thesis). The Islamic University of Gaza, Palestine.

Khader,B.(1990).Radon 222 Concentration in The Air of The Dwellings in Irbid Region-Jordan(Unpublished Master's Thesis) .Yarmok University, Jordan.

Khan, S. A., Ali, A., Tufail, M., and Qureshi, A.A. (2005). Radon concentration levels in Fatima Jinnah women university Pakistan. Radioprotection, 40(1), 11- 27.

Khattak, N. U., Khan, M.A., Shah, M.T., and Javed, M.W. (2015). Radon concentration in drinking water sources of the Main Campus of the University of Peshawar and surrounding areas, Khyber Pakhtunkhwa, Pakistan. J Radional Nucl. Chem. ,1-13.

Leghrouz, A.A., Abu-Samreh, M. M., and Shehadeh, A.K. (2013). Measurements of indoor radon concentration levels in dwellings in Bethlehem, Palestine. Health Phys., 104(2), 163-167.

Palestinian National Information Centre. (2014). Rafah city. Retrieved April 6, 2016,from: http://www.wafainfo.ps/pics/GSE_Rafah_A4.jpg

Rassas, M. (2003). *Measurement of radon and its daughter's concentration indoor and outdoor throughout Gaza Strip* (Unpublished Master's Thesis). The Islamic University of Gaza, Palestine.

Sersawi, M. (2007). *Study of the chronic radiation exposure situation in Gaza* (Unpublished Master's Thesis). The Islamic University of Gaza, Palestine.

WHO (World Health Organization). (2007). Handbook on indoor Radon A public health perspective, Geneva. P. 15.:

William R. F.(2001). A Review of residential radon case – Control Epidemiologic Studies Performed in the United States, Reviews On Environmental Health, 16(3).

Yassin, S. and Steck, D. (2000). Preliminary survey of Radon and radon Progeny throughout Gaza Strip, Palestine. paper presented at International conference on high levels of natural radiation and radon