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A Study of Factors Affecting in Increasing or Decreasing of Radon Levels in Buildings of Suwaylih Town

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Abstract

This research aimed to study the factors affected in radon levels in buildings of Suwaylih town (altitude about 900 to 1300 above the sea level) as areference to Jordan. The study was started from august, 10, 2012 to October, 10, 2012. Suwaylih Town divided into six districts namely, Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon, Al-Bashaaer districts. About 780 Passive dosimeters containing highly pure CR - 39 were distributed randomly in districts of Suwaylih town.

The indoor dosimeters were collected after three months. The collected detectors were chemically etched using 30% KOH for 9 hours at 70 ± 0.1 °C. An optical microscope was used to measure the nuclear alpha track density on the detectors surfaces.

The research results showed that radon concentration affected by many factors, for example, the average concentration in guest rooms was 83 ± 18 $Bq.m^{-3}$ and 70 ± 14 $Bq.m^{-3}$ in bed rooms, while it was 53 ± 10 $Bq.m^{-3}$ in living rooms. Morever, the concentration was about 97 ± 15 $Bq.m^{-3}$ in rooms without ventilation while the concentration was about 30 ± 10 $Bq.m^{-3}$ at rooms ventilated more than 9 hours daily.

The study also showed the concentration was relatively high 90 ± 18 $Bq.m^{-3}$ in buildings made of stones while concentration was low 47 ± 12 $Bq.m^{-3}$ in the buildings made from blocks. In addition, the concentration was different with increase in age of building, the average were 63 ± 15 $Bq.m^{-3}$, 51 ± 13 $Bq.m^{-3}$ and 39 ± 11 $Bq.m^{-3}$ in more than 25 years, between 10 - 25 years and less than 10 years, respectively. In general the radon concentration in Suwaylih town was found to be about 62 ± 13 $Bq.m^{-3}$.

Keywords: factors, radon, radon levels, buildings, suwaylih, Suwaylih town, Jordan

1. Introducation

Human exposure since its inception to radiation doses issued by the environment in which they live, these doses are known radiation dose resulting from natural environment, These doses are not significant natural gravity, where the quantities are usually less than the allowable limit. The average radiation dose equivalent exposed most people's natural resources around 2.4 m·Sv/y, with a marked contrast given the disparity of these radiation doses varied considerably from one region to another (Durrani & Badr, 1995).

Radon is the largest contributor to human exposure to natural radiation sources. Radon is a colorless gas, no taste and no smell, monatomic, a noble gas, heavier inert gases, radon density greater than the density of air, soluble in water and degrades its nucleus birth alpha particles and solid radioactive nuclei.

Radon descended from a series of uranium in crustal rocks, so the flow rate of radon varies from one region to another due to the differences in radon concentration from one area to another because of the different soils and rocks in the Earth's crust, which is considered the main source of uranium.

The average concentrations of radon gas inside buildings eight times concentrations outside the buildings in the atmosphere moderate, concentration of radon inside buildings depend on the quality of the rock and soil under construction, type walls and style ventilation. In buildings open ventilated continuing the radon concentration

inside buildings comparable to radon concentration in open air, while in closed buildings where the air not renewed constantly, it could reach the radon to dangerous levels.

There are a lot of studies about radon emissiom in the environment of the dwellings. It is possible for one house to have elevated levels of radon while a neighboring one dose not (Bajwa & Virk, 1997; Anastasion & Christofides, 2003; Mohammad & Abumurad, 2008; Al-Zubaidy & Mohammad, 2011)

1.1 Radon from Building Material

Another radon source is building material. Building materials with high uranium/radium concentration can generate continuously random in to atmosphere. Such materials, slag, fly ash, etc., could be used in some locations.

The data indicated that some materials such as aerated concrete with alum shale and phosphor - gypsum from sedimentary ores have significantly higher radium concentration than others and cause enhanced radon concentration indoors. Radon exhalation from building materials has been the subject of many studies (Ismail & Abumurad, 1996; Paredes, Kessler, Landalt, Zimemer, & Paustenbach, 1987).

1.2 Radon from Natural Gas

Like crude oil, natural gas is held in reservoirs of porous and permeable rock, containing small amounts of natural radiation. The radiation emanates from ^{238}U and its decay daughters; one of the decay daughters is ^{222}Rn, which mixes with the natural gas. This means that traces can be found in supplies of coal, oil and natural gas.

Radon is not affected by combustion, and passes through the flame. Occasional studies and measurements of radon in natural gas in many parts of the world show that levels of radon in gas cover awide range, and that some sources contain substantially elevated radon levels (Dixon et al., 2002).

The concentration of radon in natural gas at the production wells is found to vary from undetectable values up to about 40 kBq/m^3 (Gesell, Johanson, & Bernhardt, 1977). The NRPB has shown that the radon in natural gas presents no significant health risk to gas consumers.

1.3 Radon Measurement Detectors

Measurement is the only reliable way to determine levels of radon in abuilding, which are left in the building for periods from days to months. Although there are three main types of passive radon detectors, most studies used nuclear track detectors SSNTDs, especially known as CR-39 for more accurate, so we used it too (Durrani & Bull, 1987).

1.3.1 Properties of SSNTDs

These detectors are very durable, pose no great handling problems, and are not fogged by exposure to light or affected by moderate degrees of heating. Their simplicity and durability makes them particularly valuable and their robustness enables them to be used in personal dosimetry, SSNTDs have the extra advantage of retaining their record after readout, and that led to their rapid application in a wide variety of fields. But the initial application of the etched track radon dosimetry was at J. Stefan institute in 1976 (Furlan & Tommasino, 1993). Solid state nuclear track detectors have become an important tool in the investigation of the presence of radon gas, not only in indoor air but also in soil (Jonsson et al., 1995). SSNTDs have more advantage and special characteristics over other tybes of detectors, which include:

1)- Maintaining permanent records of tracks.

2)- Can integrate radon over any length of time (from a few days to one year).

3)- Little or no dependence on environmental conditions such as temperature and humidity.

4)- Passive and integrated detectors.

5)- Easy to construct and use.

6)- Small in size and cheap in price.

7)- Detect alpha but not gamma or beta radiations.

This paper aims to study factors affecting the levels of radon in Suwaylih town (northwest of Amman). Previously conducted many studies on radon in various parts of Jordan, and some of these studies are talking about measurements of radon in the soil, buildibgs and water, and others talk about the influence of radon on public health. In this paper, we talked about radon measurements in the buildings of Suwaylih town and measurements affected by different factors such as nature of using rooms, differences of floors, building materials, building age, buildings locations and passive ventilation periods.

1.4 Objectives of the Present Work

Radon is estimated to cause many thousands of deaths each year. Infact, the Surgeon General (US) has warned that radon is the second leading cause of lung cancer in the united state today. Only smoking causes more lungs cancer deaths. So that if we find any significant radon level, suggestions and recommendations will be made to the concerned government officials to reduce the risk of radon for minimum.

It seemed, therefore that it would be scientifically, socially and economically sensible to amount a nutural study of all types of radiation especially radon gas on a large enough scale to provide sufficient data to satisfy the indoor radon. After detailed discussions, the study attempts to satisfy the following objectives:

1)- To mesure the concentration of indoor radon in Suwaylih town.

2)- To suggest some recommendations to reduce and control the concentration of significant indoor radon if any.

3)- To correlate between the age of building and the radon concentration.

4)- To correlate between the age of building materials and the concentration.

5)- To correlate between floor elevation and the radon concentration.

2. Methodology

2.1 Suwaylih Town Description

Suwaylih is a town in the northwest of Amman (capital of Jordan), it is one of the oldest cities of Amman and it is a famous wellspring of water. The Suwaylih town of the most popular areas in Amman and is a link between Amman and other governorates, it is altitude about 900 to 1300 above the sea level. Suwaylih has an area of about 12 km^2 and it is residents according to the official census for the year 2007 about (68,952) people. Figure 1 shows a map of Suwaylih town which divided into six districts namely, Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon, Al-Bashaaer districts. Suwaylih town (The study area) is characterized as containing buildings of more floors and these are usually limited to 3 - 4 floors. Most of the buildings materials, like steel, rocks, cement and etc are locally manufactured.

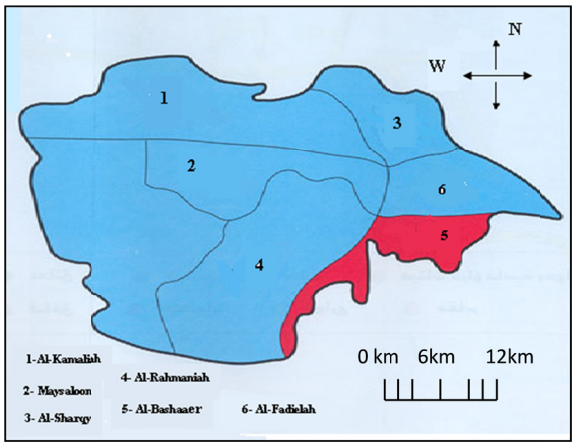

Figure 1. Map of Suwaylih town in Jordan, illustrates its districts

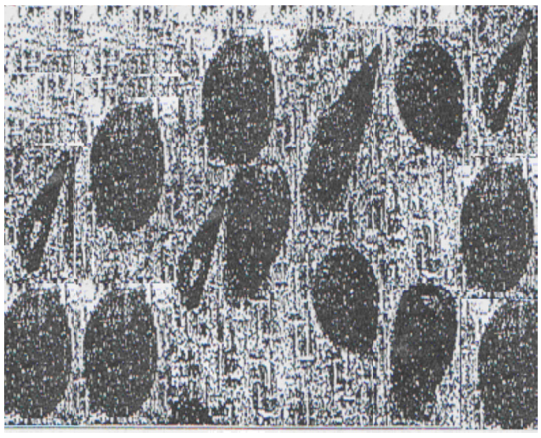

Figure 2. A alpha particle tracks in detector after zoom by optical microscopy

Suwaylih is hot in summer about 30 °C in average, in winter the average temperature drops to about 12 °C and the average rain fall is about 650 ml. The succeeding Amman Silicified Limestone Formation (santonian - campanian) is the youngest bedrock exposed in Suwaylih town. The formation consists of grey and brown, thin to medium - bedded chert, exhibiting a variety of textures ranging from homogeneous to brecciated, interbedded with gery and buff limestone, dolomitic limestone, marl, phosphatic chert, phosphate and apatite schist. These rocks were deposited in asubtidal to shallow shelf environment.

2.2 Sample Preparation and Administration

An integrated passive radon dosimeter has been used for measurement of radon. The dosimeter contain solid state nuclear track detector (SSNTDs) with dimension (1.5 cm × 1.5 cm). The detector has super grade quality of type (CR-39). Adetector fixed on the bottom of can use double face adhesive tape in each dosimeter, the dimension of container 7.0 cm in diameter, 4.6 cm in depth. The container has been covered by lid and was made a cicular hole of diameter 1.5 cm at the center of lid. The hole is covered by a piece of sponge with area of (2 cm ×2 cm) and a thikness of 0.5 cm sealed on to the interior surface of lid.

This configuration was made in order to allow the radon gas to pass through the sponge, while maintain the same calibration condition and to stop the aerosol and thoron (^{220}Rn, $t_{½}$ = 55.6 s) from entering the cup.

About 780 dosimeters had been administered in Suwaylih town (each district contain 130 dosimeters). After three months the dosimeters were collected.

2.3 Sample Collecting and Etching Condition

In CR-39, the radiation damage due to alpha particle produces broken molecular chain, free radical and etc. certain chemical reagents (etchants) dissolve or degrade these damage regions at a much higher rate than the undamaged material. The narrow damage trail is thus gouged out by the etchant, forming hole. Having the burrow - like hole in all directions at the lower, bulk etching rate. This etched track may be enlarged radially untill it is visible under an optical microscope. In this context, prior studies have showed that NaOH and KOH are the best solutions to be used with concentration ranging from 1 M to 12 M with tempreture range from 40 to 70 °C and variant etch time (Durrani & Bull, 1987).

All dosimeters had been adminstered in Suwaylih town from August, 10, 2012 to October, 10, 2012. The retrieved detector were chemically etched by using 30% KOH concentration in a water bowl with electric heater for nine hours and temperature was fixed at (70 ± 0.1 °C). Same conditions were applied for calbration dosimeters. After the completion of etching, detectors were washed by distilled water and then dried out.

2.4 Counting Background Radiation on CR-39 Surfaces

To eliminate the effect of background damage on the detector, unused detectors (four detectors from the same plate were chosen randomly and kept in the refrigerator untill the end of the experiment) were etched under the same conditions (30% KOH, 70 °C and 9 hour) and scanned under an optical microscope. The background obtained was very small and less than 3 tracks per view.

2.5 Counting Alpha Particles Tracks on CR-39 Surfaces

For counting the etched tracks, we can use an optical microscope with a magnification power of X10, X40 and some times X100. Then we counted tracks at least 25 different views for radiation resulted from radon decay is purelyrandom phenomenon. After that, the mean and standard deviation of average tracks per view on etch detector were calculated.

In the counting process of the track care must be taken to ditinguish between the tracks and dust prticles. Alpha tracks appear as black holes with different volumes and hape (See Figure 2).

2.6 Calibrations

The calibration process for the dosimeter of this type and dimensions was done in a previous work (Mohammad & Abumurad, 2008) in order to link the obtained track intensity with radon concentration. The radon concentration is calculated by using calculation equations (See Table 1).

Table 1. Relations that have been used to calculate the concentration of radon (Bq.m^{-3}) in the air of buildings where, t is exposure time and $\overline{x}$ is the mean

Lens magnification	Diameter of view area (×10^{-1} cm)	View area (×10^{-2} cm^2)	Radon concentration
X10	1.9	2.835	$C = 349.3\frac{\overline{x}}{t}$
X40	0.5	0.1963	$C = 2776.2\frac{\overline{x}}{t}$

3. Results and Discussion

The present work is study optima to evauate the level of radon in Suwaylih town. Measurements carried out using plastic detectors CR-39, it is hoped that the study will pave for future surveys to establish a Jordanian map of radon emission levels in the different sites (Mohammad & Abumurad, 2008; Al-Zubaidy & Mohammad, 2011, 2012; Al-Zubaidy et al., 2012; Abumurad & Al-Tamimi, 2005).

Radon levels obtained from the above whether as an average or spot measurements needs to be compared with the average national radon level and with the action levels set by different countries and organizations.

This paper was found that the average radon concentration in buildings of Suwaylih town was 62 ± 13 Bq.m^{-3} and this value is far below the action level set by many countries 200 - 600 Bq.m^{-3} (Hudak et al., 1996). After collecting the essential information about places where we put the dosimeters in, we will discuss now factors which may have an effect on the increase or decrease of concentration of radon gas in rooms or buildings.

3.1 Nature of Using Rooms

In this part of study, comparison has been made between radon levels in bedrooms, guest rooms and living rooms located in ground floor buildings. The average concentration in guest rooms was 83 ± 18 Bq.m^{-3} and in bedrooms was 70 ± 14 Bq.m^{-3}, while in living rooms the average concentration was 53 ± 10 Bq.m^{-3}.

This differences may be due to the long time spent in the living room during the day which need to be in suitable conditions for sitting there, so the ventilation by opening the windows and doors befor longer time than the guest and beed room which usually used during night only and keeping windows closed most of the time to avoid the dust and sometimes because the temperature will decrease in it (See Table 2 & Figure 3).

Table 2. Relation between Radon concentration (Bq.m^{-3}) and the natural of room use in ground floor buildings

Natural of using room	Frequency	Minimum	Maximum	Mean
Guest room	41	43	248	83 ± 18
Bed room	38	34	201	70 ± 14
Living room	37	26	173	53 ± 10

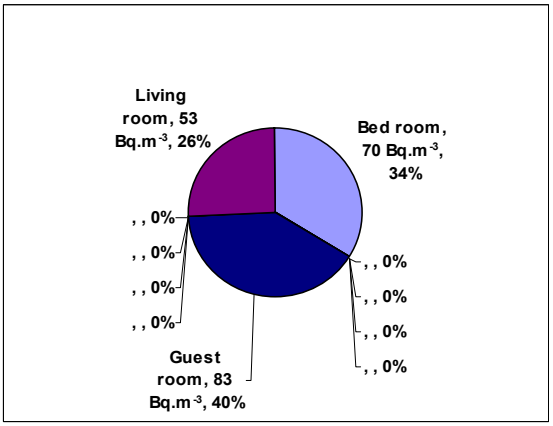

Figure 3. Variation radon level with natural of room of use in ground floor buildings

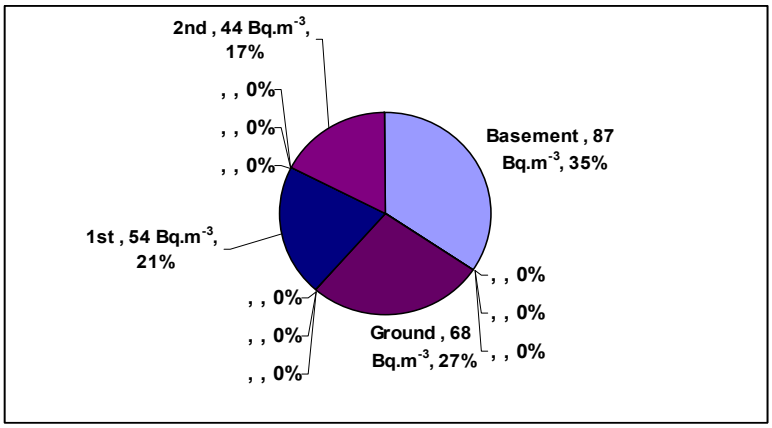

Figure 4. Variation of radon level with differences floors

3.2 Differences of Floors

Here, we discussed the relation between radon concentration and floor elevation (See Table 3 & Figure 4). The average radon concentration in 2nd floors was 44 ± 13 Bq.m^{-3}, in 1st floor 54 ± 14 Bq.m^{-3}, in ground floor 68 ± 15 Bq.m^{-3} and in basement was 87 ± 16 Bq.m^{-3}. The elevated radon concentration in basement and ground floor, as expected, may be due to the closeness of these floors to the soil which considered the main source of radon.

Table 3. relation between radon concentrations (Bq.m^{-3}) in different floors

Floor number	Frequency	Minimum	Maximum	Mean
Basement	65	35	211	87 ± 16
Ground	78	29	200	68 ± 15
1st	49	18	79	54 ± 14
2nd	34	11	64	44 ± 13

3.3 Buildings Materials

We selected the ground floor in all studied buildings and compared the radon concentration with the types of building material. Table 4 and Figure 5 shows the average radon concentration in buildings which were built from stones found 90 ± 18 Bq.m^{-3}, concrete 78 ± 14 Bq.m^{-3} and blocks 47 ± 12 Bq.m^{-3}. The high radon concentration noticed in the stone buildings. This may be due to the low porosity of stones, which did not allow to exchange with outside air. The low average level was in buildings which were built from blocks. This could be due to the high porosity, low thickness of blocks in comparison with the concrete and stones.

Table 4. Variation of radon concentrations (Bq.m^{-3}) with the type of building material

Building material	Frequency	Minimum	Maximum	Mean
Stones	28	30	205	90 ± 18
Concrete	26	15	190	78 ± 14
Blocks	22	18	179	47 ± 12

3.4 Age of Buildings

We discuss here, the relation between the radon concentrations in the ground floor at buildings built from blocks but have different ages (See Table 5 & Figure 6). Average radon concentration was found in buildings of ages more than 25 years about 63 ± 15 Bq.m^{-3}, in buildings ages 10 - 25 years 51 ± 13 Bq.m^{-3} and in buildings ages less 10 years 39 ± 11 Bq.m^{-3}.

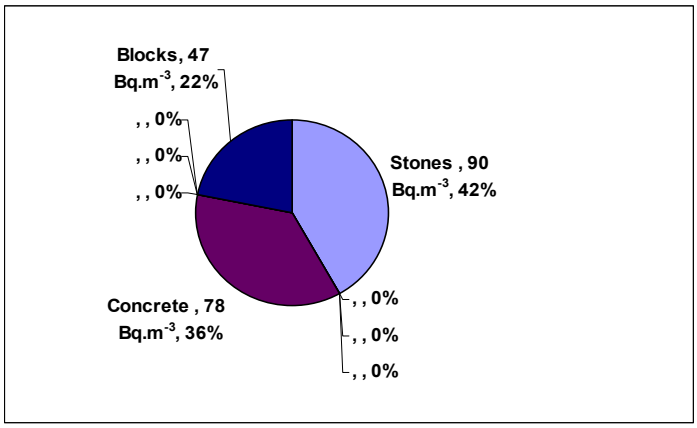

Figure 5. Variation of radon level with different of building materials

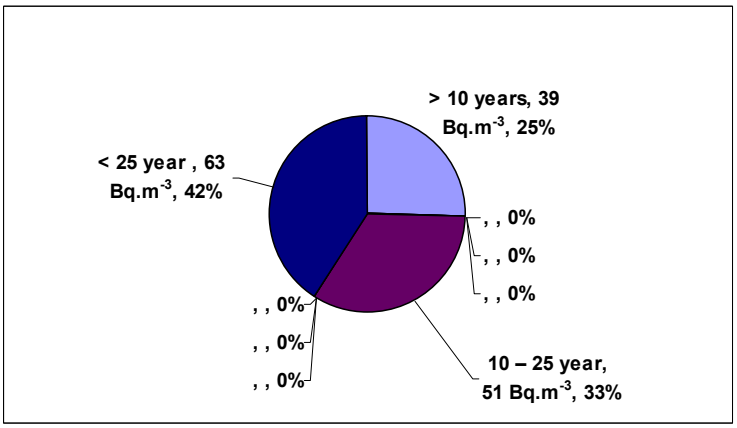

Figure 6. Variation of radon level with different age of building materials

The observed high radon concentration in buildings of ages more than 25 years may be due to the noticeable cracks in the floors and walls and sometimes unfinished walls and floors, which may allow radon gas to seep into the buildings.

Table 5. Variation of radon concentrations ($Bq.m^{-3}$) with buildings ages (years)

Building age	Frequency	Minimum	Maximum	Mean
Less than 10	22	21	74	39 ± 11
10 - 25	8	31	144	51 ± 13
More than 25	6	47	242	63 ± 15

3.5 Passive Ventilation Periods

As we see from Table 6 and Figure 7, these confirmed the essential role played by ventilation periods in reducing the radon levels in buildings.

Table 6. The relation between the ventilation rate (hours) and radon concentration ($Bq.m^{-3}$)

Ventilation period	Frequency	Minimum	Maximum	Mean
0	9	43	217	97 ± 15
1 - 5	20	51	182	46 ± 11
5 - 9	21	36	74	37 ± 10
More than 9 hours	27	11	28	30 ± 10

3.6 Buildings Locations

Suwaylih town (the study location) divided into six districts. Radon concentrations data in the ground floors was used to compare between different disricts. We found that radon levels inside studied individual building rang from 35 to 211 Bq.m^{-3} with an average 63 ± 13 Bq.m^{-3} (See Table 7 & Figure 8).

4. Conclusions

Radon concentrations in buildings in Suwaylih town were carried out using the solid state nuclear track detectors SSNTDs, applying the technique known as time - integrated closed can technique with CR - 39 detectors.

The average radon concentration in buildings in Suwaylih town have been found to be in general low and in acceptable level 62 ± 13 Bq.m^{-3}, afew high concentrations were observed in some special places. We conclude that the radon concentration levels in air inside the basement 87 ± 16 Bq.m^{-3} and ground floors 68 ± 15 Bq.m^{-3} of the studied buildings were higher than those of other floors 1st & 2nd floors. According to the age of building, the average radon concentration was higher in older buildings than that in newer ones. The study also showed that the type of use of the room has an effect on the radon concentration. The averages were 83 ± 18, 70 ± 14 and 53 ± 10 Bq.m^{-3} in Guest rooms, Bed room and Living room, respectively.

Table 7. Representation of radon concentration (Bq.m^{-3}) and buildings location

District Name	Frequency	Minimum	Maximum	Mean
Al-Kamaliah	20	37	112	62 ± 11
Al-Rahmaniah	21	40	207	79 ± 15
Al-Sharqy	22	35	186	70 ± 13
Al-Fadielah	19	28	170	64 ± 13
Maysaloon	18	30	98	58 ± 10
Al-Bashaaer	16	33	115	51 ± 9

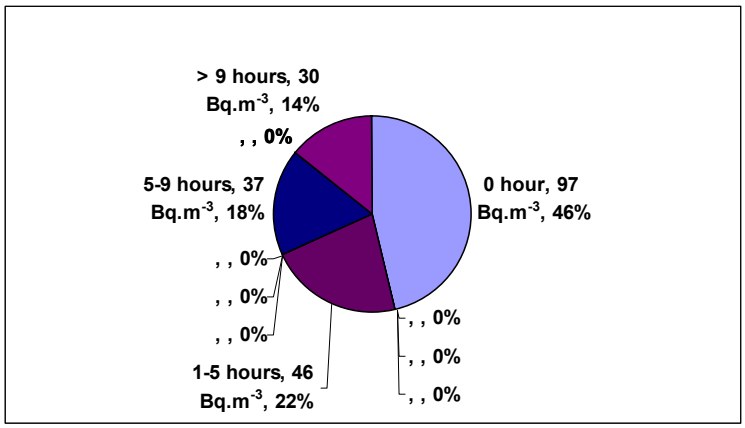

Figure 7. Variation of radon level with passive ventilation periods

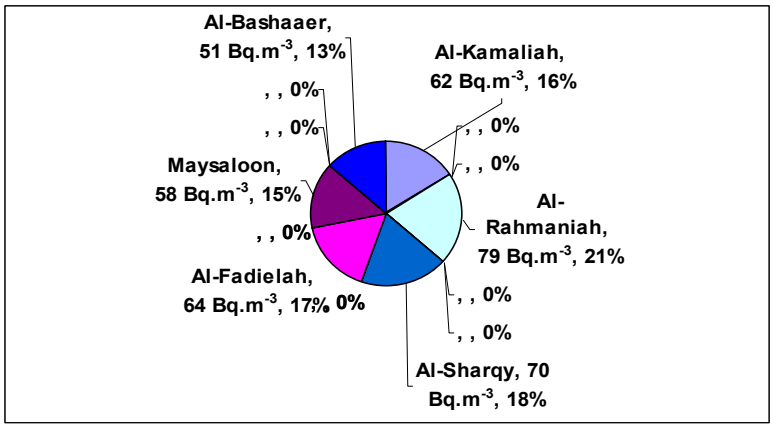

Figure 8. Variation of radon level with buildings locations

It was noticed that the average radon concentration in districts Al-Kamaliah, Al-Rahmaniah, Al-Sharqy, Al-Fadielah, Maysaloon and Al-Bashaaer closely together and found Al-Rahmaniah district had higher average radon concentration 79 ± 15 Bq.m^{-3} and Al-Bashaaer disrict was the lowere one 51 ± 9 Bq.m^{-3}. The study showed that the buildings which have the longest ventilation period (more than 9 hours during the day) have the lowest average radon concentration 30 ± 10 Bq.m^{-3}, and the buildings with no ventilation period have the highest average radon concentration 97 ± 15 Bq.m^{-3}. In addition, the concentration of radon was relatively high 90 ± 18 Bq.m^{-3} in building made of stone while concentration was low 47 ± 12 Bq.m^{-3} in building made of blocks.

5. Suggestions

The permissible level of radon exposure recommended by the local or national authority called the action level. When the indoor radon concentration level exceeds the action level, various procedures must be taken to mitigate the indoor radon concentration to alevel less than or equall to the action level. These procedures are called remedial action (Furlan & Tommoasino, 1993). Because the exposure cicumstances the same, the action level is different from one country to another. Each country has especial action level for example the action level in UK, Sweden, China and Australia is 200 Bq.m^{-3} (Hudak, 1996; Vanmarcke, Govaerts, & Oberstedt, 1996).

There are no standard techniques for all situations of exposure. However, the following general procedures may be used to reduce the radon concentration in the study (Suwaylih town):

1) improving the ventilation of the building and increasing under floor ventilation.

2) Sealing floors, walls and cracks.

3) minimize basements area and it must save for storage but not for living.

4) building materials must be selected from areas not rich in uranium and radium.

5) living areas should be chosen properly far from phosphate and granite deposits.

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