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Assessment of Radon Concentration in Dwellings in East Jerusalem, Hebron and Jericho

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Assessment of Radon Concentration in Dwellings in East Jerusalem, Hebron and Jericho

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Dedication

To the one who stay every moment with me day and night my God. To everyone helps me, to my brothers and sisters, to the soul of my mother

Amal Subhi Salim Shawar

Declaration

I certify this thesis submitted for the degree of master of Environmental Department of applied Earth and Environmental Science is the result of my own research, except where otherwise acknowledged, and this thesis has not been submitted for a higher degree to any other university or institution.

Signed:----------------------

Amal Subhi Salim Shawar

Date:-------------------------

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I would like to give a special thank for ministry of education and higher education for giving me the facilities in order to make measurements at schools and an appreciation to the staff in my school for their encourage also to those who gave me permission to use the devices deployment in their house. A big thank to God Whom without my acknowledgments would not have completed.

Definitions and Abbreviations:

Activity (A): Is measure of number of decays per second.

Dose Equivalent (H): Absorbed Dose x Biological effective dose factor.

ICRP: International Commission on Radiological Protection.

Dose conversion factor: the ratio between the weighted equivalent dose to lung and tissue weighting factor for lung.

Half-life: The period taken for the intensity of radioactive species' activity to fall to half its initial value

Radiation weighting factors: The absorbed dose is weighted by factor related to the quality of the radiation to receive, radiation weighting factor for alpha particles = 20

Recommended level: An upper limit at which mitigation or reduction in the concentration should be performed.

IAEA: International Atomic Energy Agency.

IARC: International Agency for Research on Cancer.

ICRP: International Commission on Radiological Protection.

ILO: International Labor Office.

SSNTDs: Solid State Nuclear Track detectors.

UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation.

WHO: World Health Organization.

Abstract:

Radon is a radioactive element in the ^{238}U decay series which is naturally occurring and found in different concentration in many geological formations. This radioactive gas rises from the ground, enters the atmosphere and finally dispersed in air. It can enter buildings, through cracks, or through joints in the ground floor.

The importance of indoor Radon gas has been identified for its effect of health risks which could lead to lung cancer (indoor Radon gas has been cited as a second most frequent cause of lung cancer). This effect can be reduced by studying Radon concentration in the residential areas, reducing exposure and taking serious mitigation techniques (EPA.1993).

Active continuous Radon detector RAD7, and passive solid-state nuclear track detectors Cr-39 were used to measure Radon concentrations in dwellings in East Jerusalem, Hebron and Jericho during January-2009 to February -2010. Estimated radiation does that resident exposed to. The study also aimed to study the influence of the floor number and the age of the school on ^{222}Rn concentration.

RAD7 was used in 13 schools in East Jerusalem and 150 Cr-39 detectors were distributed in the same schools and other dwellings in Hebron and Jericho. After the detectors were collected and data analyzed, Radon mean levels varied from 1.32 to 1370 Bq/m^3in schools, and 20.36 to 465.94 Bq/m^3 in dwellings.

Results showed that the Radon concentration increases when the floor number decreases until the basement. Some schools have high concentration of Radon, and some dwellings in Jericho showed high concentration of Radon with high doses that might be affected people, so ventilation rate should be increased, mitigation techniques were recommended and more researches are needed.

The highest concentration were found in East Jerusalem neighbor hoods community, where Mount Scopus Group rocks are dominant, Wadi el Quilt formation with its phosphate content expected to be the source of Radon.

The high Radon concentration area were found, where Samra formation exist .This formation with its sands, silt layer can store Radon gas for long time which cause accumulation of this gas.

The source of Radon in this case expected to be an expose gas that exposes along the fault zones.

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Chapter I

Types of Radiation and Its Sources

1-Introduction:

A wide variety of people in dwellings may be affected by high Radon concentration because it is one of the toxic substances that have health hazards (Al-Mosa, 2007). The International Labor Office (ILO) and the IAEA (International Atomic Energy Agency) acknowledged the importance of controlling Radon exposure in workplaces. These workplaces are varied in nature, such as waterworks, caves and closed-out mines open to visitors, underground stores and shopping centers, schools, kindergartens, shops, public buildings, offices and factories. For this reason, the two organizations considered it necessary to measure Radon concentration for radiation protection. (Jointly sponsored by IAEA, ILO, 2003). It is important that people are aware of the fact that there may be high Radon levels at the dwellings.

Radioactivity was discovered in 1896 by Henri Becquerel by experimenting with Uranium. He discovered that the Uranium continuously emitted radiation. Marie and Pierre Curie in 1897 found that the elements Thorium, Radium, and Polonium shared the same effect that Henri Becquerel was investigating. In 1900, Friedrich Ernst Dorn discovered that Radium emanates a gas that was first called 'Niton' (the Latin word for nitens which means shining). This gas was named Radon in 1923. Robert Whytlaw-Gray and William Ramsay isolated Radon in 1908, and they determined its density. They found that it was the heaviest known gas and its density 9.72 grams per liter; it is about seven times dense as air (Al-Mosa, 2007). Pierre and Marie Curie In 1902 isolated the radioactive element Radium. Marie and Pierre Curie together with Henri Becquerel for their work on radioactivity shared the Physics Nobel Prize in 1903. Marie Curie in 1911 was also awarded the Chemistry Nobel Prize for the discovery of the elements Radium and Polonium. (Speelman, 2004).

Radon is the radioactive gas with atomic weight 222 and atomic number 86. (^{222}Rn). It is odorless, it has no color and it is the heaviest noble gas at room temperature. Radon is an inert gas and therefore chemically inactive (Synnott,et al,2006). It is the result of the radioactive decay ^{226}Ra by emission of an alpha particle in the ^{238}U decay series Fig (1.1). The half-life is 3.825 days. There are quite a few other isotopes of Radon besides^{222}Rn; the most notable ones are ^{220}Rn that is known as Thoron and ^{219}Rn is known as Actinon. Thoron is formed in the Thorium ^{232}Th decay series where in ^{224}Ra decays form it Fig (2.1). Thoron has a half-life 55.6 seconds. Actinon on the other hand is formed in the ^{235}U decay series when ^{223}Ra decays to Actinon; it has a half-life of about 3.96 seconds Fig (3.1). ^{222}Rn is considered the long lifetime relative to the other isotopes. Radon has significantly more time than other isotopes to diffuse through the materials into the indoor environment in buildings such as schools and kindergartens or the outdoor atmosphere. This Radon formed relatively close to the earth's surface can diffuse through the indoor by pressure gradients (Bigu, 1984).

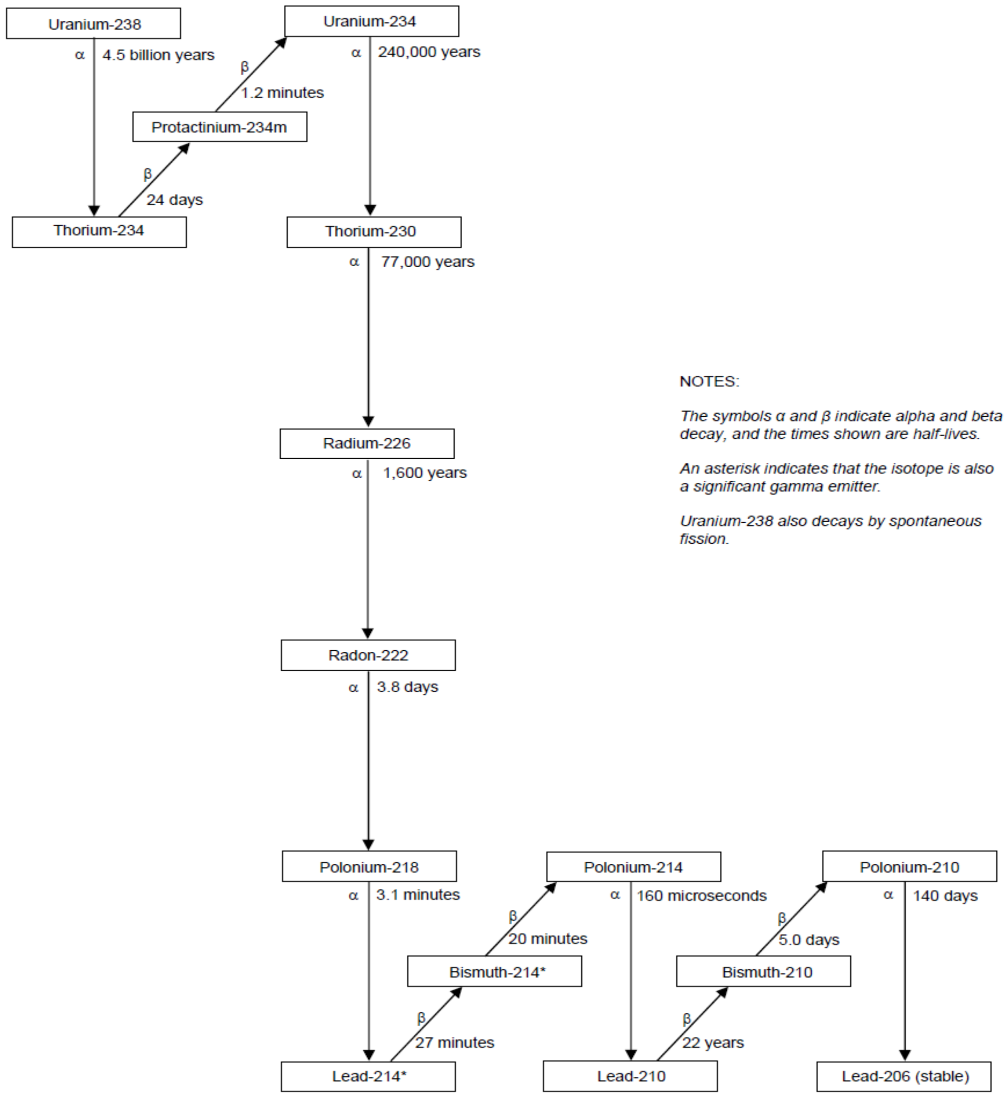


Figure1. 1: Natural Decay Series Uranium -238 (Argonne National Laboratory, 2005).

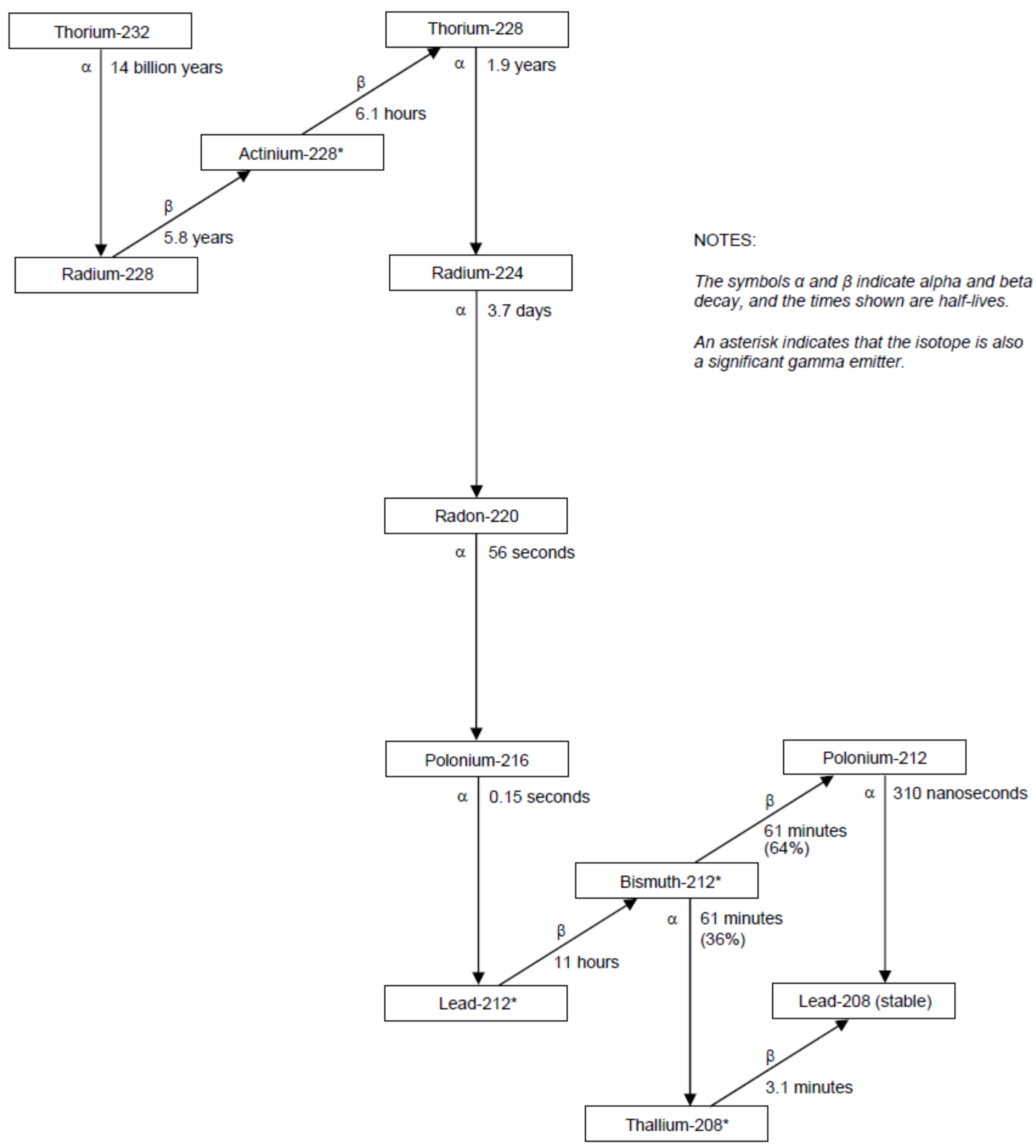


Figure1. 2: National Decay Series Thorium -232 (Argonne National Laboratory,2005).

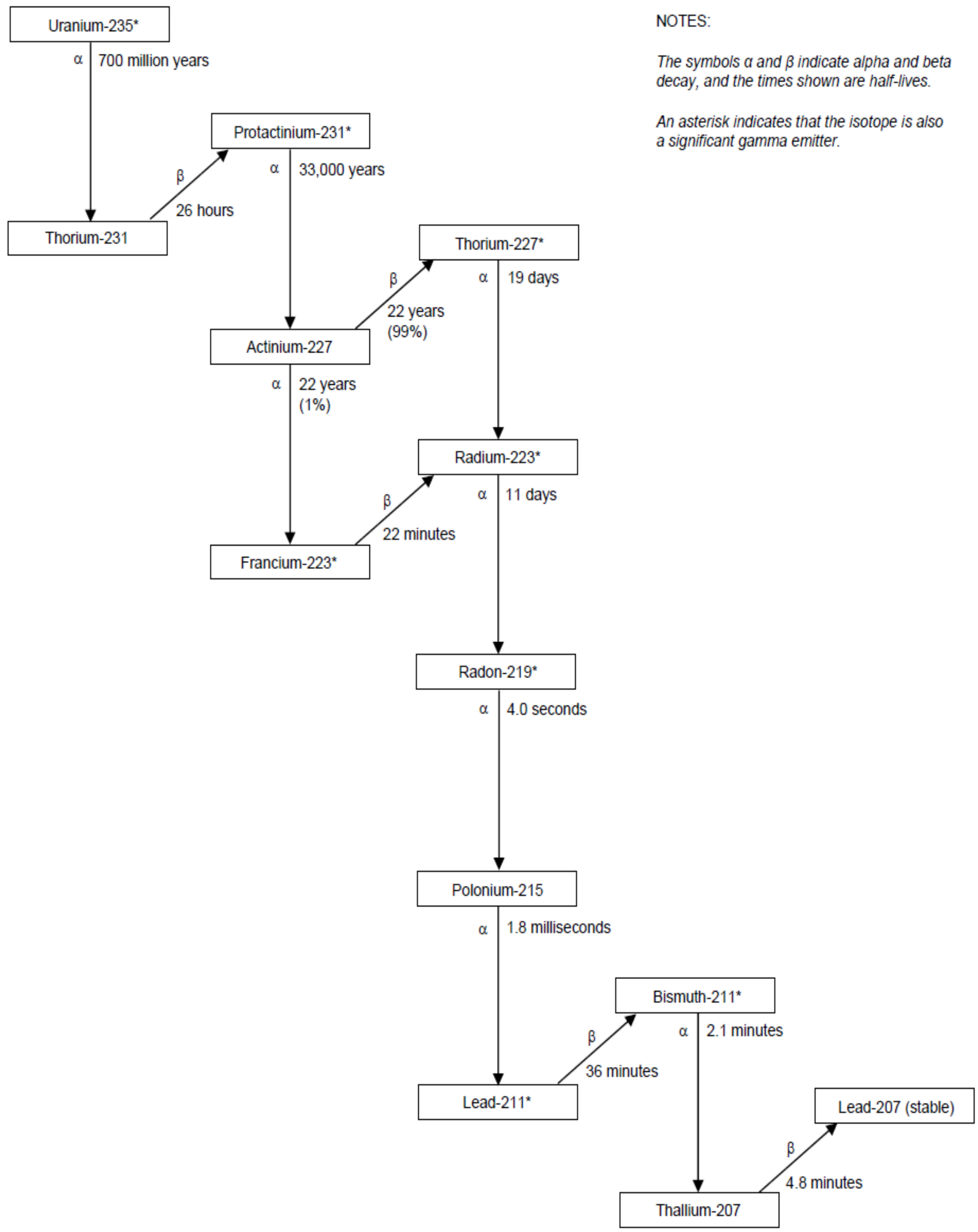


Figure1. 3: Natural Decay Series: Uranium -235. (Argonne National Laboratory, 2005).

1.1. Types of Radiations

Radiation is the emission of energy from the nucleus of unstable atom which is known as radioactive material. The unstable atom will become stable by releasing excess energy in the form of energy or particles usually results in the formation of a new element, (Environmental Health and Safety, 2000).

Radiations in general were classified into two categories depending on its ability to form ions during interactions with matter, these are:-

1-Non-ionizing radiations do not have enough energy to emit electrons from electrically neutral atoms. Examples of this type; Visible light , radio waves, microwaves, infrared light, radar and some ultraviolet light.

2-Ionizing radiations, which have enough energy to emit electrons from atoms .Ionizing radiations, include alpha particles, beta particles, gamma rays, X-rays, and neutron.

1.2 Sources of Radiation

The majority of people will be exposed to more ionizing radiation from natural background than from their jobs because they live in radioactive world (Environmental Health and Safty, 2000). The average person in the United States receives about 3, 60 mSv of ionizing radiation every year. "About 3 mSv per year is from natural sources. (Eckhardt, 1995).

1.2.1: Natural Sources:

The major natural sources of radiation are Radon, cosmic radiation, terrestrial radiation and internal of our bodies. Radon comes from the radioactive decay of Radium. Radon travels from soil rocks and enters the home from the cracks and other grabs and emits alpha radiation. Although it cannot enter the dead cover of the skin of our body, it presents a danger when it taken into the body. Cosmic radiation comes from the sun and outer space. At higher elevations, the amount of atmospheric shielding decreases and the annual dose increases. The third sources of natural sources terrestrial radiation which comes from the ground (rocks, building materials and drinking water), when the concentration of Uranium and Thorium increased in the soil the terrestrial radiation levels have elevated. The forth source is the internal of our bodies; the food and water contains trace amounts of natural radioactive materials which deposit in our bodies, and cause an internal exposure to radiation. Most of our internal exposure comes from Potassium-40. (Environmental Health and Safty, 2000; Akerblom.G, 1995).

1.2.2 Man-made Sources:

The difference between man-made sources and natural sources of radiation is the place from which the radiation originates; these sources could be divided into three categories:

1-Medical radiation sources which is the greatest exposures to average individuals.
2-Consumer products.
3-Nuclear facilities and atmospheric testing of nuclear weapons.

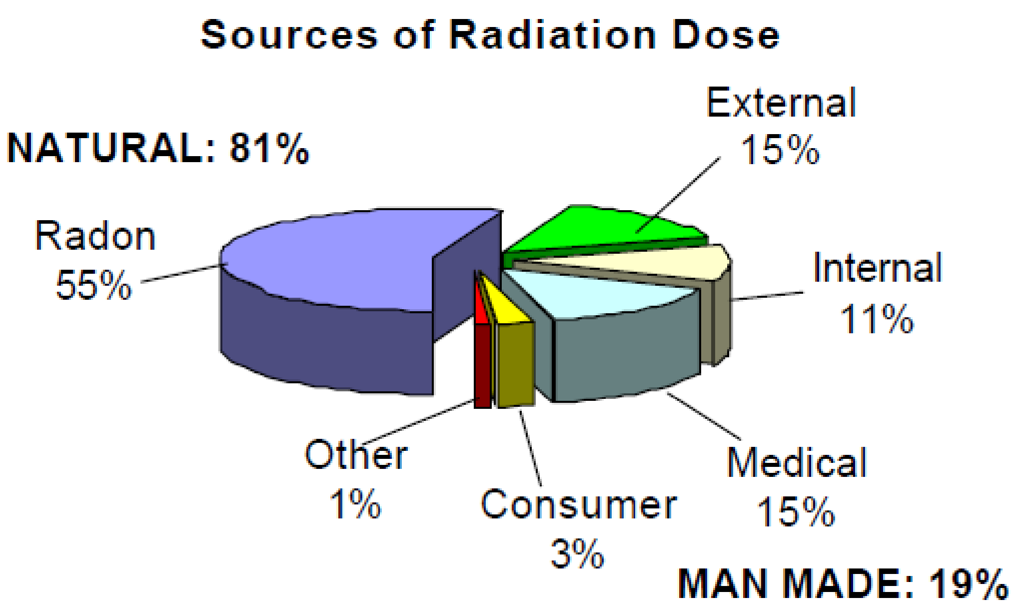


Figure 1.4: Average Radiation Exposure from manmade and natural radiation. (Hall, 2002).

Natural radiation contributes about 81% of the annual dose to the population which represents Radon, internal, and external radiation. Man-made radiation contributes the remaining 19% that includes medical, consumer and other. Natural and man-made radiations do not differ in effect or kind. Man-made radiation is generated in a range of commercial, medical and industrial activities. The most familiar and, the largest of these sources of exposure are medical X-rays (Hall, 2002; Eckhardt, 1995).

Radon is the most important radioactive sources in air because more than fifty percent of human radiation dose received from all sources is due to Radon. Fig (1.4).

1.3 Radiation Units and Quantities:

Ionizing radiation is measured in terms of the energy of radiation ,strength or radioactivity of the radiation source, level of radiation in the environment, and the amount of radiation energy absorbed by the human body,(Nemangwele,2005)

The most important radiation units are activity, absorbed dose, and the dose- equivalent.

Activity (A); is a measure of the number of decays per second. The historical unit of activity is the Curie, which is 3.7×10^{10} disintegrations, or radioactive decays per second, and the SI unit of activity is the Becquerel.

Another unit uses to measure the concentration of Radon is Working Levels (WL) which is defined as any combination of short-lived Radon decay progeny in one liter of air is ultimately releases 1.3×10^5 Mev of alpha energy during decay. So (1 p Ci/L =37Bq/m^3) and (1WL=3.7×10^3 Bq/m^3).

Absorbed Dose (D); is the energy absorbed per gram of tissue in the body. Its typical unit is rad. Rad is the abbreviation of Absorbed Radiation Dose; it is defined as the deposition of 100 erges of energy in 1 gm of material (1 rad = 100 erg/gm). The rad will be replaced by its SI equivalent, the grey(Gy) the deposition of 1 joul of energy in 1 kilogram of material(1 Gy =1 J/kg=l00rad).

The Dose-Equivalent (H); the absorbed dose (D) multiplied by a biological effectiveness factor, and typically expressed in sievert. The absorbed dose doesn't take the type of the ionization radiation into account .For example; alpha radiation leaves several hundred times an ion track denser than that of a beta particle. This means that if an alpha particle and a beta particle penetrate tissue, the deposition of energy for the alpha particle is several hundred times more focused. Generally, one rad of alpha radiation is about twenty times more effective at causing cellular damage than one rad of gamma or beta radiation. This shows us that alpha radiation cause cancer by its damage to the cell.
Health physicists account using a radiation-weighting factor (W_R), for these differences, that represents the effectiveness of each type of radiation to cause biological damage. The factors are determined by measuring the occurrence of various biological effects for equal absorbed doses of different radiations.

The product of the radiation weighting factor and the dose (W_R x D) is a more direct measure of the biological risk and is called the dose-equivalent, H. The idea is that equal dose-equivalents generate equivalent amounts of biological damage.
(Eckhardt, 1995). A corresponding unit of dose equivalent in SI units called the sievert (Sv). (1 Sv = 100rem).

Table (1.1) shows the summary of the radiation quantities and its units, and the conversion from the traditional units to Standard International units (SI).

Table 1. 1: SI units and equivalents for traditional units of radiation.

Exposure Unit	**SI Unit**	**Conversion for Traditional Unit**	**Traditional**
Activity	Bq	1 Ci = 3.7×10^{10}Bq	Curie
Absorbed dose	Gy	1 Gy = 1 J/Kg	rad
Dose equivalent	Sv	1 Sv = 100 rem	rem
Activity concentration	Bq/m^3	1.0pc/l=37Bq/m^3	-

The limit should be expressed as an effective dose of 1 mSv in a year for public exposure (ICRP, 2005). WHO proposes a reference level of 100 Bq/m^3 to minimize health hazards due to indoor radon exposure (WHO, 2009). While ICRP recommended that the action level is from 200-600 Bq/m^3. So schools were recommended to take action to reduce the level of Radon when it reaches high concentration.

During 1990s, numerous countries have decreased their design and action levels for Radon indoors. Recommended action levels for some countries are given in table (1.2).

Table 1. 2: Recommended action levels for the annual average Radon concentration in air in dwelling (European Commission, 1998).

Country	**Action Level (Bq/m^3) in Dwelling**	**Country**	**Action Level (Bq/m^3) in Dwelling**
USA	150	Czech Republic	400
UK	200	Finland	400
EU	200	Norway	400
Germany	250	Sweden	400
Ireland	200	Switzerland	1000

1.4.1: Sources of Radon Gas

Uranium and Thorium respectively possess half-lives of 14.1 x 10^9 and 4.47 x 10^9 years. Both common and naturally-occurring elements are the main sources of Radon gas which found in different concentration in soil and rock (Al-Mosa, 2007). The primary source of indoor Radon is its immediate parent ^{226}Ra . Some types of rocks, e.g. shale, granite and phosphate deposits; often show much higher concentration of Radon gas than Uranium concentration in crustal rocks. The underlying soil and rock are important sources of indoor Radon gas (Al-Sharif, and Abedelrahman, 2001). Recent experimental and theoretical studies suggest that soil may be the predominant source in several cases where the Radon indoor concentration is high. (Nero, and Nazaroff, 1984). Other sources of radon are water usage, building materials, outside air, and burning natural gas used for cooking purposes and for space heating. (Charles and Kunz, 1998; Lugg, and Probert, 1997).

It is commonly accepted that Radon from soils and rock is the main source for indoor Radon (Charles and Kunz, 1998). Radon concentration depends on two factors; its availability within the soil’s pores and the rate of Radon migration. The main soil parameters influencing the rate of Radon entry into near buildings are: grain-size distribution, porosity, permeability, moisture content, and diffusivity. (Lugg, and Probert, 1997; Shehadeh, 2008).

Building materials contribute little to the total Radon activity-concentrations of indoor air, wood materials tend to emit the least Radon, while those contains granite, cement and some clay bricks emit more(Al-Mosa ,2007). Two factors influences on Radon exhalation rates from building materials, moisture content of the material and atmospheric pressure. (Lugg, and Probert, 1997).

Water supplies is another sources of indoor Radon, it can be important source if the water drawn from underground sources Radon released from water to the air during cooking, having a shower or bathing this increasing Radon concentration levels. (Bochicchio,et al, 1995; Lugg ,and Probert,1997; Shehadeh, 2008).

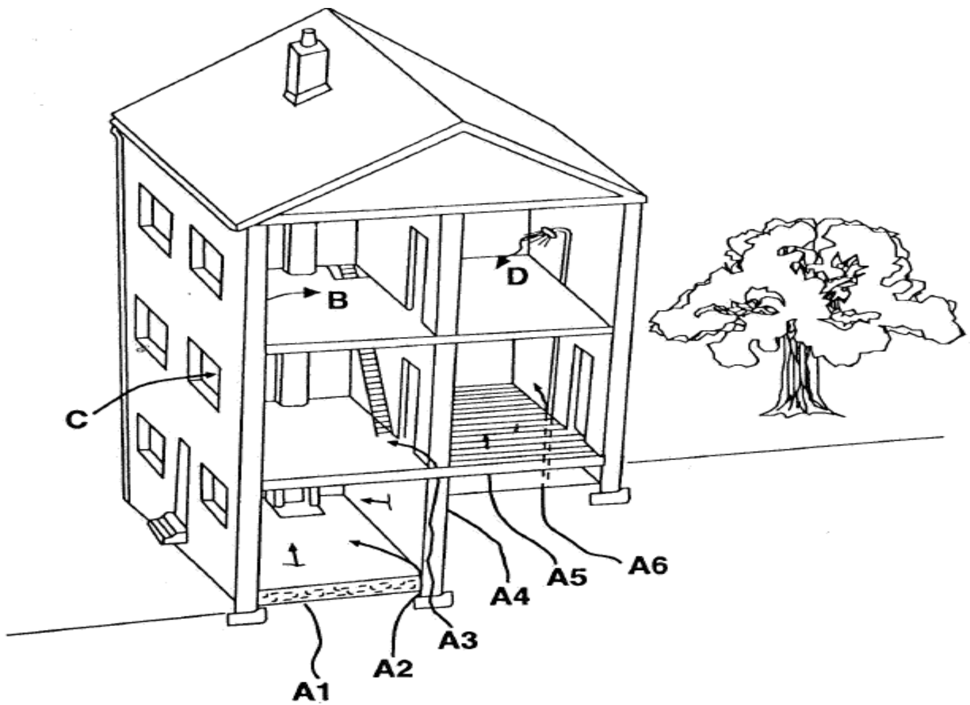
There is some variability of Radon levels in gas from different sources and it would be prudent to keep this source of exposure under review (Dixon,2001), e.g. in Venezuela the Radon content of natural gas and its contribution of 30% to the indoor Radon level (Bohus, et al,1995).

Outsider air usually acts as a diluting factor, due to its normally low Radon concentration.
In outdoor air the Radon concentration is generally related to atmospheric pressure, with higher values during night. Taking into account recent measurements, the mean value of outdoor Radon concentration adopted by UNSCEAR in its report has been changed from 5 to 10 Bq/m^3 for continental areas and somewhat less in coastal regions (Bochicchio, et al,1995).

1.4.2: Indoor Radon Sources

Radon moves up from the soil through the ground to the air above and into our home or schools through cracks in walls, floors joints and other holes in the foundation. Dwelling

traps radon inside, where it can build up. Any home, school or kindergarten may have a Radon problem. This means new and old ones, well-sealed and drafty dwelling, and dwelling with or without basements. (Al-Sharif, and Abedalrahman, 2001; Bochicchio, et al, 1995).
Emanation from soil gas is the main cause of Radon problems. Sometimes Radon enters the dwelling through well water. Some building materials can cause Radon problems by themselves. Fig (1.5) below shows Radon entry from soil and other sources:



A-entry of Radon from soil through; B-radon exhalation from building material
A1-cracks in solid floors C- entry of radon with outside air
A2-construction joints D -radon released from water
A3-crackes and cavities in walls
A4-cracks in walls below ground level
A5-gaps in suspended floors
A6-gaps in service pipes

Figure1. 5: Indoor Radon Sources and Entry Routs (Bochicchio.et al, 1995).

1.4.3: Health Effects of Radon.

Radon is known as human carcinogen. Exposure long times to elevated Radon concentrations causes an increased risk of lung cancer (EPA, 1993; Darby and Hill, 2003). There is some uncertainty about the magnitude of Radon health risks; however, scientists are more certain about Radon risks than risks from most other cancer-causing environmental pollutants. This is because estimates of Radon risk are based on studies of cancer in humans (underground miners). EPA estimates that Radon may cause about 14,000 lung cancer deaths in the U.S. each year. However, this number could range from 7,000 to 30,000 deaths per year (EPA, 1993). European countries (Darby and Hill, 2003) and the U.S. Surgeon General have warned that Radon is the second-cause of lung cancer deaths (EPA, 1993). Figure (1.6) shows the estimated deaths caused by Radon relative to deaths resulting from other causes.

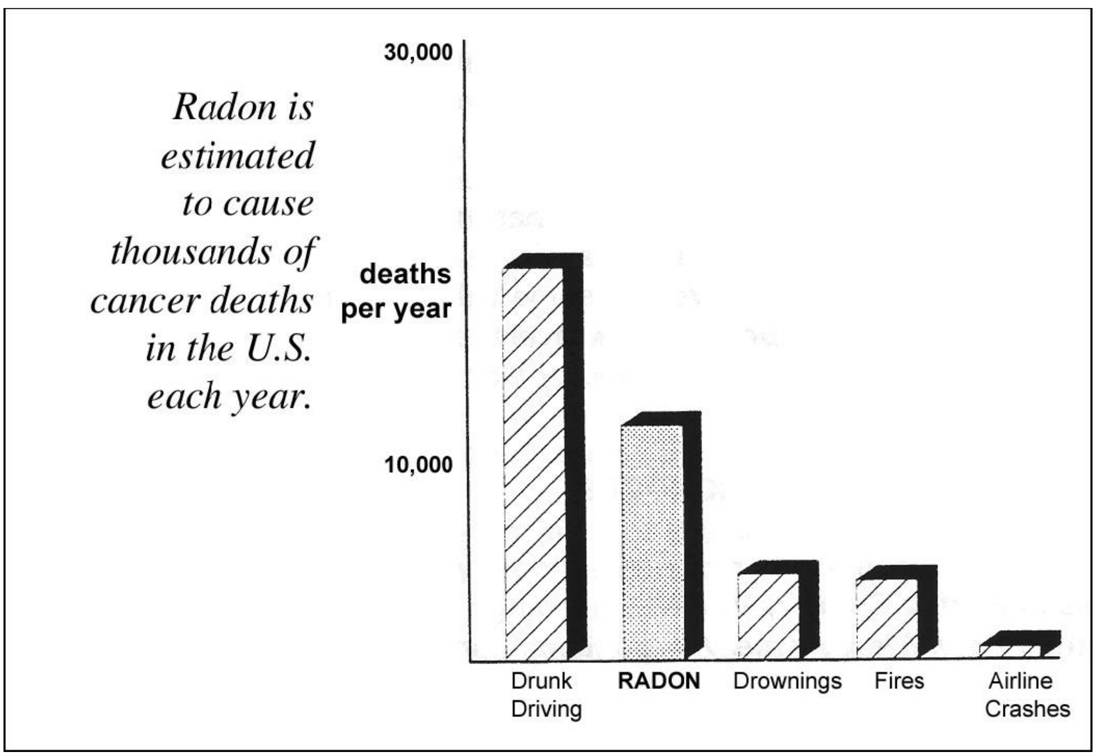


Figure1. 6: The estimated deaths caused by Radon relative to deaths resulting from other causes (EPA.1993).

An individual's risk of getting lung cancer from Radon depends mostly on three factors which are the level of Radon, the duration of exposure, and the individual's smoking habits (Al-Mosa, 2007). Risk is increased as an individual is exposed to higher levels of Radon over a longer period of time. Smoking combined with Radon is an especially serious health risk. The risk of dying from lung cancer caused by Radon is much greater for smokers than it is for nonsmokers (EPA, 1994).

Like other inhaled radioactive materials, Radon progeny attached to aerosol particles, when it inhaled into the lungs, it will be deposited in different parts of the respiratory tract. (Kendall, and Smith, 2002).

The Radon itself is exhaled in general before it decays and emits alpha particle but the Radon decay product, may remain there for several hours emitting alpha energy transfer to the nearby living tissue damaging the human cells causing cancer (Lugg, and Probert, 1997; Ismail, 2006)).

When a cell exposed to ionizing radiation, the following things are possible effects of radiation on cells: (Environmental Health and Safety, 2000)

1. There is no change.
2. Cells repair the damage and operate normally.
3. Cells are damaged and operate abnormally.
4. Cells die as a result of the damage.

Figure (1.7) shows the possible effects of ionizing radiation on exposed cells

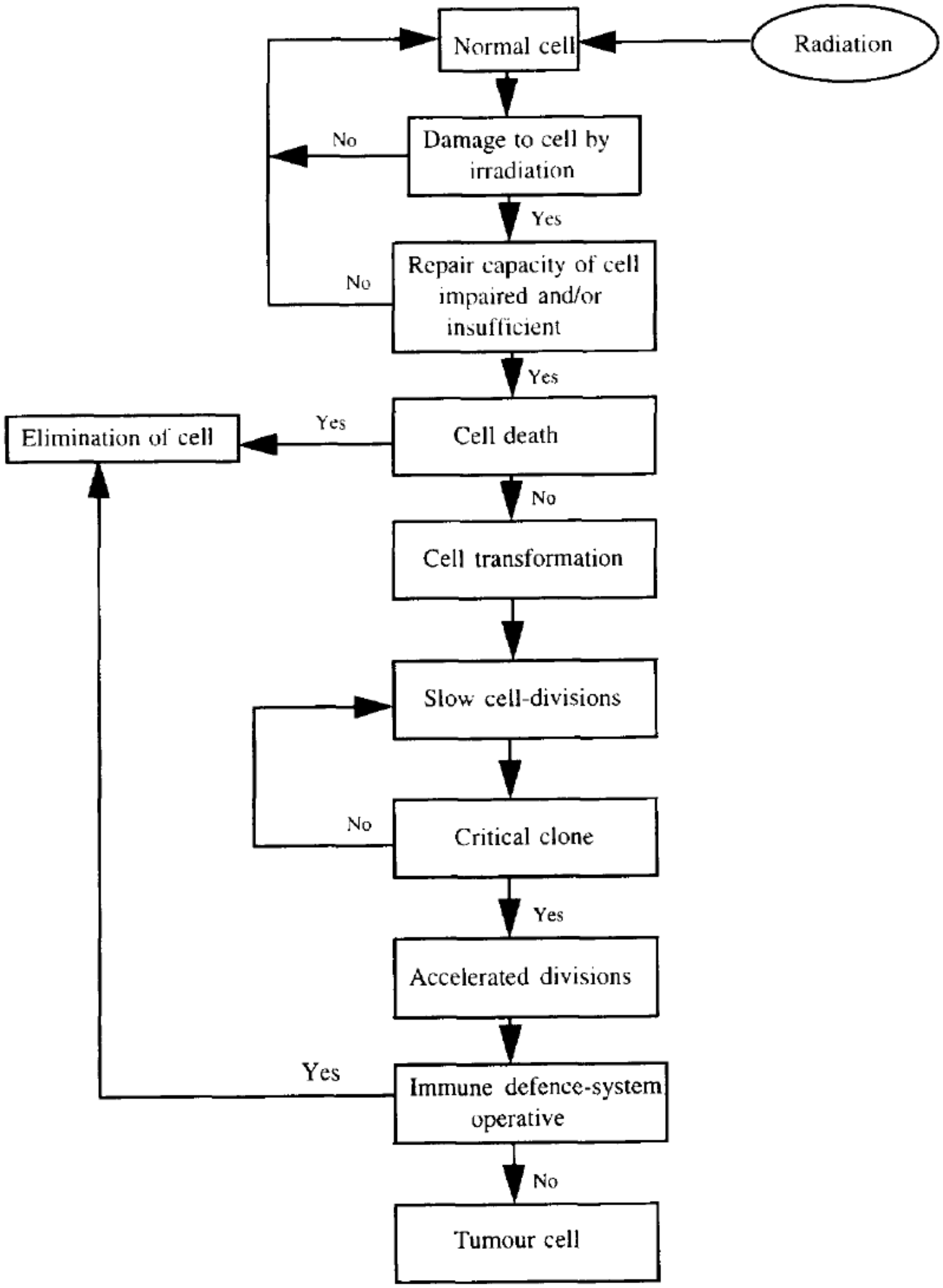


Figure1. 7: The sequence of events for cancer due to human exposure to radiation. (Lugg and Probert, 1997).

1.5: Study Area:

The study area locates in the central part of Palestine, East Jerusalem, the study sites in Abu Dis, Al Azaria, and Al Swahereh .The measurements were taken in the government schools in these sities the study extended in some private schools, homes and stores in Jericho. Aquabit Jabber camp and Hebron, the map of these places is in the following figure (1.8).

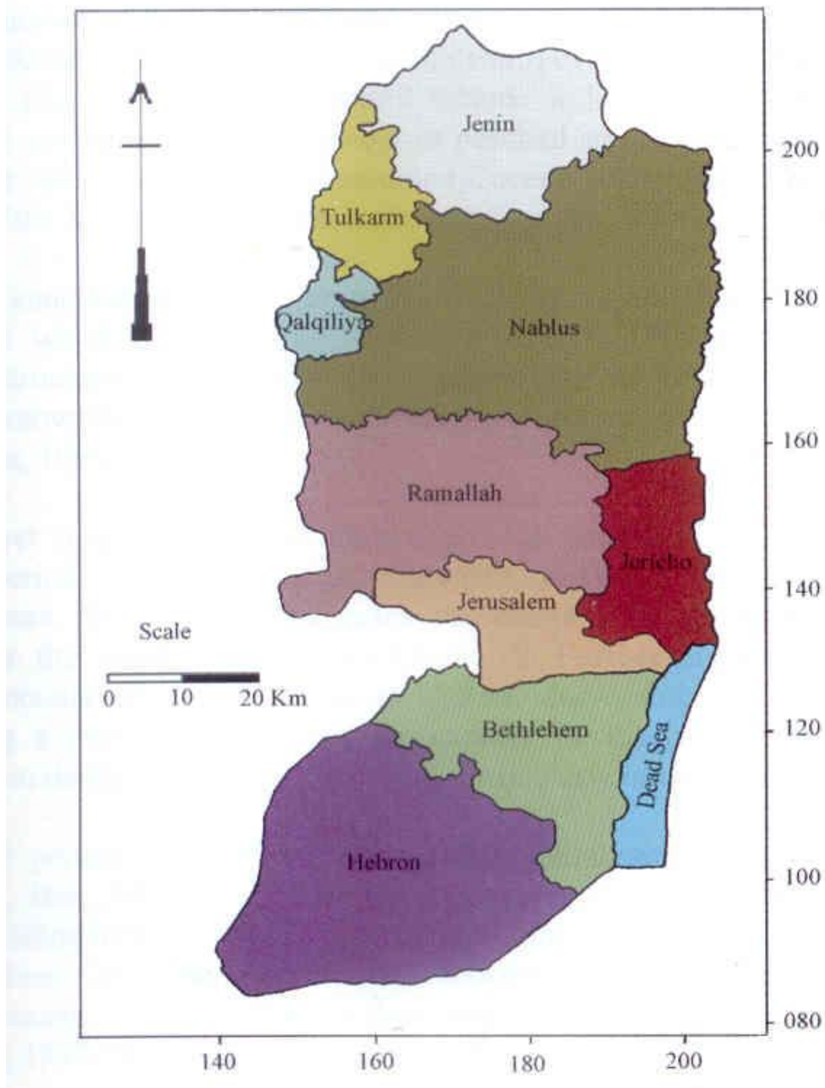


Figure 1.8: Map illustrated Jericho, Hebron and Jerusalem. (Abdul Jaber.Q. et al., 1999).

1.6: Objectives.

There is a consensus among several organizations including : the International Agency for research on Cancer (IARC); the International Commission on Radiological Protection(ICRP); the United Nations Scientific Committee on the effects of atomic Radiation (UNSCEAR); The World Health Organization (WHO); and the National Radiological Protection Bodies of Germany, the Nordic countries, the United Kingdom and the United States of America said that there is a strong link between the exposure to indoor Radon decay products, and the occurrence of the lung cancer, thus these previous organizations recommend that there is a need to limit the exposure of humans to indoor Radon and its decay products in the home and work place and schools. (Lugg, and Probert, 1997).

The aim of this thesis is to carry out a survey of indoor ^{222}Rn concentration in dwellings in East Jerusalem, Jericho and Hebron. And to find out the amount of exposure of the people.

The objectives of this study are as follows:

1. To measure Radon concentration inside schools, and some houses.
2. To estimate the radiation doses that students and resident are exposed to through the year.
3. To determine the influence of the floor level in the buildings with the Radon concentration.

Chapter II

Literature Review

2.1: Introduction

There is a consensus among several organizations as mention before that there is a great link between the exposure to indoor Radon decay products, and the occurrence of the lung cancer, thus these authorities recommend that there is a need to limit the exposure of humans to indoor Radon and its decay products in the houses, workplaces, and schools by making a survey of indoor Radon everywhere to reduce the risk of Radon. Determine the concentration of Radon and its equivalent dose is important.

2.1.1 Some of the locally studies in Palestine:

(Shehada, 2008) study had measured indoor Radon levels in dwellings and schools in summer and winter to find a national average assessment for Radon level in Palestine. The methodology for Radon detection is based on alpha-counting of Radon and its daughters, using passive device Cr-39 detectors, which were distributed in dwellings in the middle zone of Palestine. Radon levels varied from 30-655 Bq/m^3 in summer, and from 40-984 Bq/m^3in winter. The annual average of Radon level was 111 Bq/m^3.

(Leghrouze, et al, 2007) study was measured the indoor Radon concentration levels in some locations spread in Hebron province, Palestine. Using the Cr-39 detectors during the winter season of the year 1999/2000 gives the results showed that the Radon concentration levels were vary from 23 to 580 Bq /m^3. It was found that most of Radon concentration levels in houses and schools are below the low reference levels limits. Most of the high-radon concentration levels were found in storage rooms which are not painted.

(Dabayneh, and Awawdah, 2007) study in Dura dwellings was examined the Radon concentration levels, the annual effective dose equivalent, and the exhalation rate due to inhalation of Radon and its progeny on residents in Dura dwellings by using Cr-39 detector, which is put in different rooms for almost 70 days. The results obtained that Radon concentration levels in bathrooms and kitchens are higher than bed rooms and living rooms. The calculated mean effective dose is 1.20 mSv/yr. None of the Radon levels exceeds the recommended concentration assigned by the International Commission on Radiological Protection.

(Dabayneh, 2006) study was made in four girl government schools in Tarqumia town in Hebron city in Palestine. The aim of this study is to carry out a survey of Radon levels in the four girls' schools and to estimate the annual effective dose equivalent due to inhalation of Radon and its daughters by young pupil. Using Cr-39 alpha track detectors. Detectors were put in all classes of all four schools in the region under investigation. The detectors were collected after 70 days and were analyzed. The results show that the annual effective dose equivalent in the schools was varied from 0.62 mSv/yr to 12 mSv/yr within an average of 1.76 mSv/yr. This value was slightly higher than the average annual effective dose limit of global (1.3 mSv/yr):

(Rasas et al, 2005) study was measured and detected the indoor Radon level throughout Gaza Strip. Radon concentrations in the houses were measured using passive integral solid-state track detectors Cr-39. Dosimeters were distributed inside the houses of the middle region of Gaza strip. These houses are chosen to be representative of the whole region. Results indicate that Radon average concentration range from 13.36 up to 83.82 Bq/m^3 with a maximum value of 97.01 Bq/m^3.

(Awawda, 2001) study was measured the indoor Radon concentration in schools in south region of Palestine, using Cr-39 detectors as passive detector, and active one called work level meter. The results show that the concentration of Radon in the area low and in acceptable level (20-40 Bq/m^3), few relatively high concentration were observed in closed storage rooms and basements (40-100 Bq/m^3), so recommendation for further studies.

(Abu-Samreh, 2005) study was measured Radon concentration in dwellings of some selected zones in Yatta City in Palestine. The dosimeter used in this study Cr-39 detectors. In results, indoor Radon concentrations that exceed the USA-action level of 150 Bq/m^3 were found in basements having unpainted concrete walls and bad ventilation. Poor ventilation reduces air exchange rate. Radon concentrations in Yatta city are higher than in other villages surrounding Hebron City. The high Radon concentrations are mainly due to the presence of stone mines.

(Richter et al 1997) monitoring aimed to determine the distribution of Radon levels in a school, in Jerusalem. Several sets of measurements were done using different methods; Charcoal canister detectors and the electrets ion chamber. Results show that some rooms with high levels of Radon were noticed exceeding 200 Bq/m^3. These findings indicate that it would be prudent to test all schools and public buildings and periodically retest and reevaluate high-risk schools and public buildings.

(Shirav, and Vulkan, 1997) study Radon-prone areas were mapped on the basis of direct measurements of Radon ^{222}Rn in the soil/rock gas of all exposed geological units. Using a modified alpha track detection system, the results show high Radon levels mainly in rocks of Mount Scopus Group, which comprised of chert-bearing marly chalks, rich in phosphor which acts as the major Uranium source.

(Hasan,1996) study was measured indoor Radon concentration at Hebron University in Palestine using Cr-39 detectors which is sensitive to alpha particles .The average of Radon concentration was found to be 29.8 Bq/m^3.This leads to an annual effective dose equivalent of 1.49mSv/y.

2.1.2: Some of Studies Outside Palestine.

(Al-Jarallah, and Fazal-ur-Rehman, 2006) In Saudi Arabia were used Passive Radon detectors to measure indoor Radon concentration of Al-Jauf region in Saudi Arabia, which is geological formation of this area is mainly sandstone, siltstone and shale. The Radon concentration varied from 7 to 168 Bq/m^3 with an overall average of 35 Bq/m^3 for all surveyed dwellings.

(Abu-Jarad, et.al, 2003) study in Saudi Arabia was gained representative indoor Radon data of the Eastern area and to evaluate that with similar data from two special cities in the

Western area. The Eastern area is rich in oil and natural gas wells which might give an additional source of indoor Radon. In the Western area, Madina is situated in a geological area rich in radioactive materials and granite rocks which contain U, Th and K, while Taif is situated above sea level and is built on a rocky foundation. Taif is also classified as a ‘cold’ city in Saudi Arabia. Houses and schools were covered in this survey, Radon concentration, measured by a passive system and then complete by an active system, the Radon concentrations varied from 1 Bq/m^3 to 137 Bq/m^3 with an overall average of 22 Bq/m^3. For all surveyed dwellings. None of the dwellings showed Radon concentration within the action level of the International Commission on Radiological Protection except one city, which showed a value of 535 Bq/m^3. This city also showed the highest spread in Radon concentration. The highest average Radon concentration was found 40 Bq/m^3, while the lowest average concentration was found 8 Bq/m^3. The average Radon concentration in schools varied from 15 up to 32 Bq/m^3.

(Abdel Ghany, 2006) study In Egypt carried out a set of Radon measurements, using Cr-39 solid state nuclear track detector, in different rooms of dwellings in Cairo. These houses were located in apartment complexes built of the same building materials. The results showed bathrooms and kitchens had a significantly higher Radon concentration and exhalation rate compared with both other rooms and the outdoor levels.

(Kullab, et.al, 2001) study in Jordan, studied seasonal variation of ^{222}Rn concentration levels inside and outside specific locations in Jordan by using passive detectors (Cr-39), and an active device (Radon Monitor RM3). The study sites were located in an area that used to be an old phosphate mine. They found that the maximum value of Radon concentration in air inside the dwellings was 1532.9 Bq/m^3 during the winter season, and the minimum one was 46.3 Bq/m^3 during fall season, as measured by the passive dosimeters. While the highest and lowest readings of the Radon monitor RM3 were 892 Bq/m^3 and 4 Bq/m^3 during fall and summer seasons, respectively.

(Kullab, et.al, 1997) study was determined Radon indoor concentration in 74 Kindergartens in Amman, Jordan during winter season by Cr-39 detectors, results show that Radon concentration inside rooms range between 40.7_ 193.5 Bq/m^3.

(Amrani, 2000) study in Algeria was aimed to carry out a survey of Radon levels to estimate the effective dose equivalent in schools and homes due to inhalation of Radon and its daughters by young students using passive track etching method with the LR-115film, type II .The measured indoor radon concentration in different town locations of Algiers has a mean value of 25.6± 4 Bq/m^3 in schools and 29.8± 4 Bq/m^3in homes. The mean effective dose equivalent due to inhalation of Radon and its daughters in homes0.88 mSv/yr was nearly 4 times higher than the average dose value found in schools 0.25mSv/yr.

(Venoso, et.al, 2009) study In Italy measured Radon concentration in 30 schools using the solid state nuclear track detectors and LR115detectors.The results show that the Radon concentration in scientific laboratories is higher than in the classrooms. It can be seen that high concentrations occur also at levels over the ground.

(Orgun, et.al, 2008) study In Turkey Cr-39 detectors were deployed in 58 rural dwellings of Ezine in order to measure Radon concentrations in the summer season. The highest Radon levels (600 Bq/m^3) were found in three dwellings because of insufficient ventilation. These dwellings have Radon activity over the range of intervention level (200– 600 Bq/ m^3) as recommended by the International Commission on Radiological Protection. After excluding these three values, the range of Radon concentration varied from 9 to 300 Bq/ m^3, with an average of 67.97 Bq/ m^3. The lower Radon concentrations corresponded with that area where ophiolitic and sedimentary rocks are prevalent, whereas the regions of higher average concentrations were essentially consist of granitic and volcanic rocks. Average annual Radon effective dose rate calculated was 1.71mSv /y.

(Hadad, et al.2007) study In Iran was to determine the Radon concentration in houses using a solid state nuclear track detector technique (CN 85 type) to determine whether the safe health limit of 200Bq/m^3 was exceeded for the people of New Mirpur Azad in Kashmir and surrounding areas. The dosimeters were put 2.5 feet below the ceiling of houses and were exposed to Radon for 60 days. The results show that the average Radon concentration in the dwellings of New Mirpur area is within the safe health limit. (Iqbal, et al. 2008).Another indoor survey in four cities in Iran was carried out by using passive and active measurements by solid state nuclear track detectors and portable Radon gas surveyor studying dwelling structures, geological formation, elevation and temperature as variation parameters. The maximum record concentration was 2386Bq/m^3 during winter and the minimum concentration was55Bq/m^3 during spring. The annual effective dose average is between 3.43-5mSv/yr.

(Papaefthymiou1, and Georgiou, 2007) study In Greece determined the Radon concentration levels in the classrooms of public primary schools in Patras area, and to examine some factors that affecting the indoor Radon concentration, such as the age of the buildings and constructed materials. The concentration of Radon was measured by LR-115 SSNTD film for six months. The Radon concentration in schools vary from 10 to 89 Bq /m^3.

(Bahtijari, et. al, 2007) study In Kosovo measured indoor air ^{222}Rn concentrations in 15 rooms of five elementary and in six rooms of one high school in Sharr, Kosovo, using alpha scintillation cells. Values decreased from basement to first floor.

(Banjanac, et al, 2006) study in Serbia determined Radon concentration by etched track detectors in secondary schools, in the spring Cr-39 detectors distributed in the schools for 3 months, in the results of indoor Radon concentration measurements 35 Bq /m^3 is the highest read so it is accepted results.

(Radolic, et.al, 2006) study in Croatia was started at the end of 2003 in order to determine the distribution of the annual indoor Radon concentrations in Croatia with the identification of the Radon prone areas and to estimate the percentage of dwellings where Radon concentration exceeded certain reference values (200 or 400 Bq/m^3) so as to choose the future Croatian action level. Using passive track etching method with strippable LR-115 SSNTD film, type II. The detectors were put in 800 randomly selected homes. The obtained values of arithmetic means of Radon concentrations in each of 20 counties were in the range from 33 to 198 Bq/m^3, respectively. The percentage of dwellings with concentrations above 400 Bq/m^3 was 1.8 %.

(Rydock, et.al, 2001) study in Oslo was aimed to measure the concentration of diurnal Radon in a school and office in Norway in Oslo by continuous Radon monitor. The average Radon concentration for the 8-day measurement period in the school in the classroom in the measurement period was 2205Bq/m^3,and the average Radon concentration in the office in the measurement period was 1915Bq/m^3.Diurnal measurements in the office and a school demonstrate that high measurements from devices yielding integrated concentrations over weeks or months can be the result of very low concentrations in the daytime, and very high Radon concentrations at night These results suggest that the only method to accurately assess Radon exposure in day-use buildings is to include measurements of Radon concentrations restricted to the hours when the buildings are essentially in use.

(Vaizoglu, and Guler, 1999) study in Turkey was aimed to measure the level of Radon in domestic dwellings in Ankara, using Cr-39 passive alpha track detectors during the period 1996-1997 indoor Radon concentrations were measured in approximately 200 houses during a 6 months' winter period. Values obtained were between 2 and 408 Bq/m3.Median values for living rooms and bedrooms were 19 and 25 Bq/m^3, respectively. It was found that the indoor Radon concentration was associated with the presence of cracks on the walls, the building materials used for the walls and the type of ventilation in the house.

From these literatures we can find that Radon concentration is district by many factors:

Type of the rock especially Uranium source, stone mines, Radium soil, cracks of the walls, type of ventilation, and constructed materials. Most of the studies used alpha track detectors because it's inexpensive and accurate.

2.2 Comparison between Radon Concentration in Some Countries

In the following table 2.1 there is a comparison between levels of Radon concentration and the annual effective dose equivalent for many different countries.

Table 2.1: Comparison between Radon concentration and equivalent dose in some countries.

Region	**Place of study**	**^{222}Rn Concentration Bq/m^3**	**Estimated Doses mSv/y**	**References**
Greece	Schools	Arithmetic mean 231 with range 40 to 958	-	Clouvas,et .al(2009)
Kuwait	Dwellings	24.2 ±7.7to 462 ±422	1.3 ±0.4to 23 ±21	Maged,(2009)
Kashmir, Pakistan.	Dwellings	Range from 27 ± 6 to 169 ± 4,	Range from 0.78±.15 to4±.1	Rafique,et. al(2009)
Pakistan	Schools	15 to 140	0.40±.09	Rahman,et.al(2009)
Pakistan	Schools	Varied from 18±7 to 168±5 With an average 52±9	0.49	Rahman, et.al, (2009)
Bangladesh	Dwelling	Vary 245-2570	1.195	Farid(1993)
Saudi Arabia	Buildings	Exceed 150	-	Al-Ghamdi,Khougeer, and Baig(2007)
UK	Workplace	400	-	Denman, et, al (2004)
Kosovo	Schools	Exceed 400	-	Bahtijari et al (2006)
Ireland	Schools	200 to 1000	-	Synnott, et. al (2004)
Greece	Dwelling	30±6to1700±110	4.5	Louizi et al (2003)
Slovenia	Schools	Exceed 400	Range from 0.04-6.10	Vaupotic(2001)
Italy	kindergartens schools	Range from 10-89 with average23.2 ±14.8	0.38	Malanca, et.al(1997)

Chapter III

Instruments and Methodology

3: Introduction.

There are two different methods to measure Radon activity concentration using in this study. The first measurement technique is continuous active Radon sampling. The device is a continuous Radon monitor active Radon sampling which requires electrical power that can be used to make multiple readings over a given period. The second method is passive Radon sampling which is considered passive, and requires no electrical power as in the case of the continuous Radon monitor. The passive Radon detector used in this work, give the average Radon concentration during the measurement period The two techniques will be used to complete different tasks in measuring the factors that affect diffusion of Radon.

There are three general types of alpha particle detectors that are designed to measure Radon, namely Solid state alpha detectors, Scintillation cells, and Ionization chambers. The RAD7 falls in the first category, the detector consists of a semiconductor material (Nemangwele, 2005). RAD7 works on the principle of alpha particle detection. (Durridge, 2000). The following section describes the principle of the detectors.

3.1: Instruments

3.1.1 Continuous Radon Monitor -RAD7 Solid State Detector.

RAD7 is a true, real-time continuous radon monitor .This means that varied Radon concentration levels can be observed during a measurement period. This is very helpful, in the sense that one can investigate the factors influencing the Radon concentration with time. The factors may include temperature changes and humidity. (Speelman, 2004).

RAD7 possesses a periodic-fill cell. The cell is filled with air by means of a small pump that draws air into the cell once during each pre-selected time interval. In this defined cell, the Radon or the ^{218}Po may decay, and the decays are counted and the cycle repeated. (Guan,et al.2002;Speelman, 2004).

RAD7 Radon detector uses a solid state detector. This alpha detector is a silicon ion-fixed detector. The semiconductor material (e.g. silicon) converts the alpha radiation from the decay of the radionuclide (e.g. ^{218}Po or ^{214}Po) into an electrical signal directly. One essential advantage of the device in Radon or Radon progeny detection is the fact that it can electronically reveal the energy related with the incoming alpha particle. In this way, the specific radionuclide can be known, ^{214}Po with energy of 7.69 MeV, or ^{218}Po with an alpha radiation of 6.00 MeV. (Guan,et al.2002;Speelman, 2004).

RAD7 possesses an internal sample cell of about 0.7 liter and has a hemispherical shape as can be observed in Figure (3.1). Inside of the hemisphere is covered with an electrical conductor and a high voltage power supply charges the inside of the conductor to a potential of about 2000-2500 Volts relative to the detector. This creates an electrical field throughout the cell. The electrical field propels the positively charged particles onto the detector in the periodic-fill cell. When ^{222}Rn atom decays within the cell leaves ^{218}Po
(a positively charged) behind, which is accelerated onto the detector and sticks to it. The ^{218}Po nucleus has a relatively short half-life and when it decays, it will have a 50% chance of entering the detector where it will produce an electrical signal, and the energy of the alpha particle can be identified. (Durridge, 2000; Speelman, 2004).

The electrical signal recorded from the decay of the radionuclide is then amplified, filtered and sorted according to its force. The RAD7 determines the Radon concentration by measuring the radioactivity of decay products.

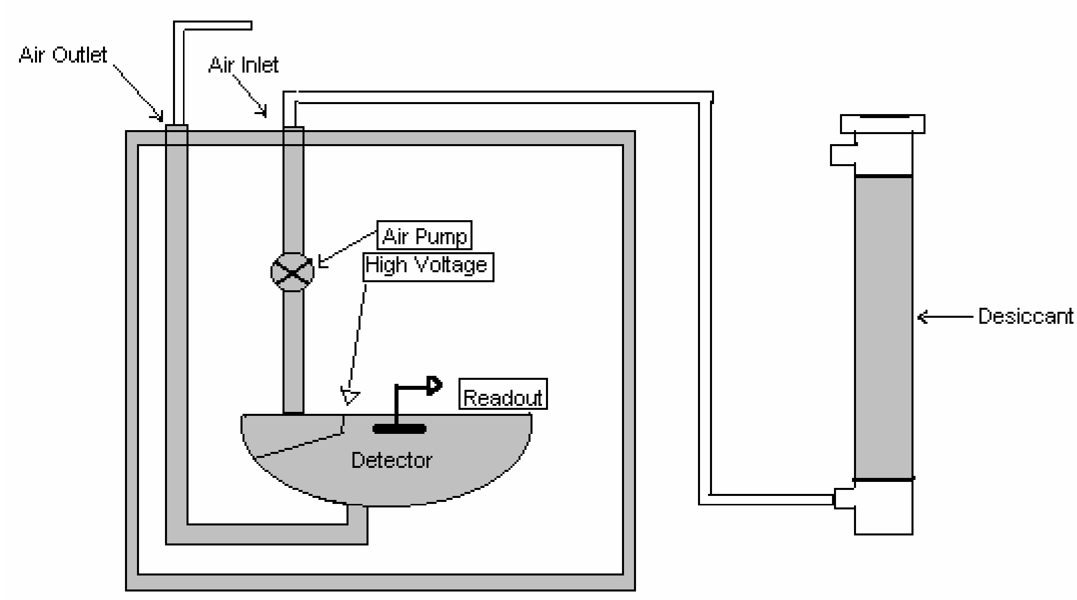


Figure 3. 1: Schematic of the RAD7 detector. (Speelman, 2004).

The detector produces a spectrum. A very important feature of the spectrum is the absence of the 5.49 MeV peak (^{222}Rn alpha energy) in the spectrum since ^{222}Rn decays in the air in the cell of the detector and not on the surface or close to the detector. The purpose of the desiccant in figure (3.1) is to absorb any moisture that was pumped into the tubing to keep the air relatively dry. However, the Radon might also get adsorbed on the desiccant granules. This becomes a problem at very high Radon concentrations, in which case the RAD7 should be purged. (Speelman, 2004).

3.1.2 RAD7 Spectrum and scale of Alpha Energies

The electrical signal converted to alpha radiation amplified and conditioned by the electronic circuitry of the detector, then converted to digital form. The RAD7 possesses a microprocessor that receives the signal and stores it in the detector's memory. The signal that is stored is associated with the decay of a specific radionuclide and in the process of accumulating many of these signals, a spectrum can be formed. (Speelman, 2004). The RAD7 divides the spectrum's from 0 – 10 MeV.

The spectrum is divided into 200 channels that correspond to 50 keV (0.05MeV) per channel. Ideally, in the spectrum, the 6.00 MeV alpha peaks would only be a needle spike as represented in Fig (3.2), but this is not the case with the RAD7 because of the electronic noise in the detector as well as the amplifier. Another cause for the broadened peaks is the fact that some of the alpha particles enter the detector at a small angle.

An increase in the temperature also causes electronic noise, and in turn affects the tail of the peaks. The analysis of the spectrum is simplified because the electronics of the RAD7 is manufactured to group the 200 channels into 8 windows. Those windows are listed as A – H in alphabetical order. (Guan,et al.2002).

Window A covers the energy range of 5.40 – 6.40 MeV, so clearly the alpha particle with energy 6.00 MeV from the ^{218}Po decay will fall in this region. All the counts detected in that region divided by the live time (duration of the time that it took to collect the data), gives the count rate. This is all stored in the detector memory. (Guan,et al.2002).

A spectrum is printed by RAD7 after the run that includes windows A – D.
This can be seen in Figure (3.2). Windows E – H make up the composite window O.
Window O is the sum of all the counts arising from energy ranges of windows E – H. The different windows contain:

1) Window A: Total counts from ^{218}Po decay, derive new Radon
2) Window B: Total counts from ^{216}Po decay, account for Thoron
3) Window C: Total counts from ^{214}Po decay, derive old Radon
4) Window D: Total counts from ^{212}Po decay, account Thoron
The counts from the composite window are due to noise in the system.

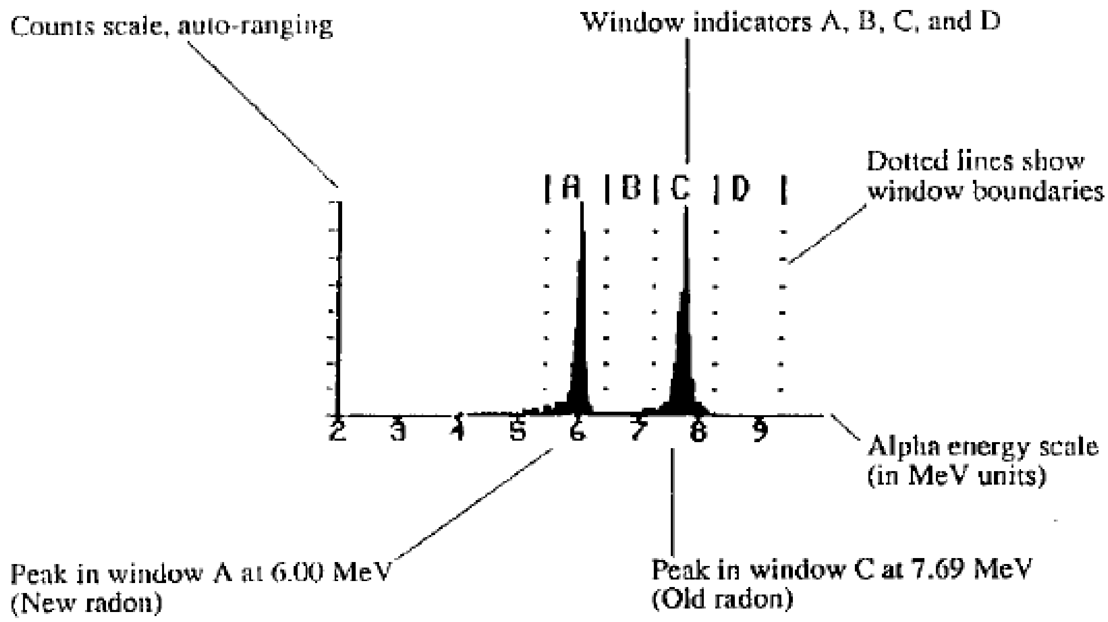


Figure 3.2: A spectrum of alpha energy includes windows A-D (Durridge, 2000).

3.2.1: The alpha track detector

This includes alpha track detectors which no require electrical power to perform its function (Al-Mosa, 2007). The alpha track detector is solid state nuclear track detector is constructed in such a way that a thin piece of plastic or film is fixed at the bottom of a plastic cup using double-sided tape (blue-tack) (Al-Sharif, and Abedalrahman, 2001). The plastic cup allows for Radon to diffuse into the device via a filtered covered opening. The purpose of the filter is to keep dust and Radon decay products out. Another function of it is for structural support for the detector housing. (Speelman, 2004). See figure (3.4).

Radon eventually decays in the detector and the emitted alpha particles hit the film and the radiation damage causes a track on the film. The immediate Radon decay products may also give off an alpha particle on decay, and hence, leave a track on the plastic. The films are then placed in a caustic solution such as sodium hydroxide, often at elevated temperatures for several hours (Dabaynah,and Awawdeh,2007),which enhance the tracks left on the plastic and these tracks can then be counted by an automated system or via optical microscope method. The number of tracks on the film would give an indication of the Radon concentration, provided a few conversion factors are used from the calibration process (Speelman, 2004).

3.2.2: Characteristics of Solid State Nuclear Track Detectors:

They are being used in various fields, inexpensive sensitive to alpha particles emitted by Radon, insensitive to beta and gamma rays, unaffected by humidity, low temperature, light, and moderate heating, they do not require an energy source, their high melting point allows them to exposed directly to heavy charged particles, and they are the only detectors which exists in the form of minerals. (Al-Mosa,2007),but like any other detectors there are some disadvantages ,they require long period of time to measure the radon concentration, so it may lost for the long period of measurement. Cr-39.That is used in this study is made of polyallyl diglycol carbonate, it has been found the most efficient and sensitive detectors among all the plastics to all alpha particles. (Misdaq, and Ouguidi, 2008; Kullab, 2002).

The typical Cr-39 dosimeter in the figure (3.3) below:

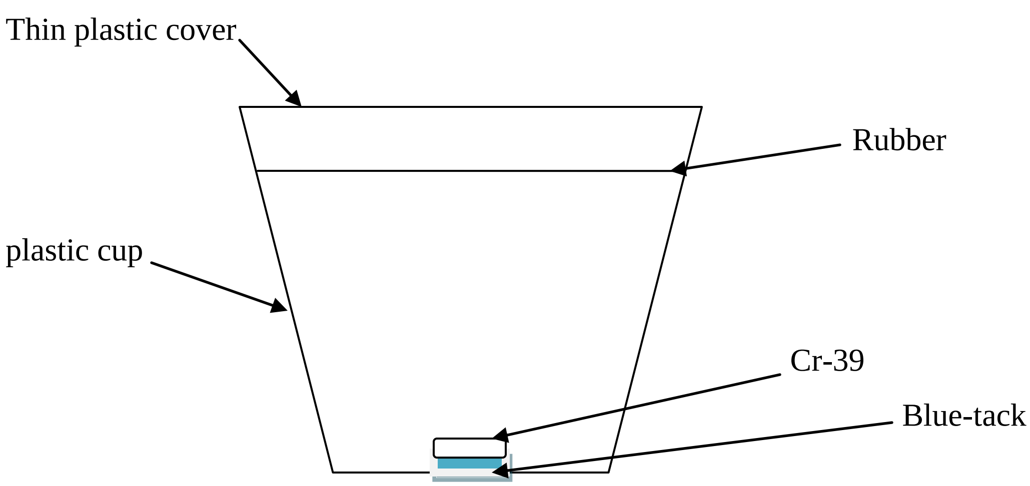


Figure 3.3: typical Cr-39 dosimeter.

3.3: Measurements Technique.

The measurement of Radon concentration inside the schools and other dwellings were made using a Radon continuous monitor RAD7 and alpha track detectors Cr-39, this measurement were taken during 1/2009 and 2/2010.

RAD7 used only in one room in every school, which is safe for the detector, RAD7 was installed in the room on a table figure (3,4),windows and doors were closed for 48 hours (measurement period) .The detector run on and measured the concentration of Radon in the room with its temperature and humidity day and night every hour. The sites were RAD7 was installed in it are presented in table (3.1) with the measuring site, construction date ,the floor number, and the city that the device put in it.

Figure 3. 4; RAD7 device in a class room in a school in the study area.

Table 3. 1: using of RAD7 detector in schools with the measuring site, date of construction and the floor number.

School Name	**Date of Construction**	**Measuring Site**	**The Floor Number**
Anata primary School for Girls (Anata)	1970	Pray room	1
Yusef Al Kateeb Primary School for Boys(Al azaria)	1948	Physical Education	2
Al Masharee Primary School for Girls (Al Azaria)	1976	Headmistress room	2
Al Masharee Primary School for Boys(Al Azaria)	1971	Second class	1
Al Azaria Primary School for Girl (Al Azaria)	1936	Headmistress room	1
Al Azaria Secondary School for Girls(Al Azaria)	1990	10^{th} class	1
Abu Dis Primary School for Boys (Abu Dis)	1983	Library	1
Abu Dis Primary School for Boys(Abu Dis)	1933	Class room	1
Abu Dis Primary School for Girls (Abu Dis)	1997	Theatre	Basement
Abu Dis Secondary School for Boys(Abu Dis)	1950	Supervisor room	2
Al Swahreh Secondary School for Boys (Al Sawahereh)	1937	Headmistress room	1
Al Swahreh Secondary School for Girls (Al Sawahereh)	1965	6^{th} class B	Basement
Maskat Secondary School for Boys (Al Azaria)	2007	12^{th} class	1

Table (3.2) contain the start and end dates of using RAD7 in the first measuerements.

Table 3.2: using RAD 7 in schools within start and end date.

School Name	**Start Date**	**Measuring Site**	**End Date**
Anata primary School for Girls (Anata)	30/6/2009	Pray room	2/7/2009
Yusef Al Kateeb Primary School for Boys(Al azaria)	08/7/2009	Physical Education	10/7/2009
Al Masharee Primary School for Girls (Al Azaria)	26/8/2009	Headmistress room	28/8/2009
Al Masharee Primary School for Boys(Al Azaria)	21/6/2009	Second class	23/6/2009
Al Azaria Primary School for Girl (Al Azaria)	24/8/2009	Headmistress room	26/8/2009
Al Azaria Secondary School for Girls(Al Azaria)	28/6/2009	10^{th} class	30/6/2009
Abu Dis Primary School for Boys (Abu Dis)	30/4/2009	Library	2/5/2009
Abu Dis Primary School for Boys(Abu Dis)	09/6/2009	Class room	11/6/2009
Abu Dis Primary School for Girls (Abu Dis)	22/7/2009	Theatre	24/7/2009
Abu Dis Secondary School for Boys(Abu Dis)	28/4/2009	Supervisor	30/4/2009
Al Swahreh Secondary School for Boys (Al Sawahereh)	30/8/2009	Headmaster room	1/9/2009
Al Swahreh Secondary School for Girls (Al Sawahereh)	27/7/2009	6^{th} class B	29/7/2009
Maskat Secondary School for Boys (Al Azaria)	05/7/2009	12^{th} class	7/7/2009

Figure (3.5) shows the location of the schools that RAD7 detector were installed in Anata ,Al Sawahereh,Abu Dis and Al Azaria cities in East Jerusalem.

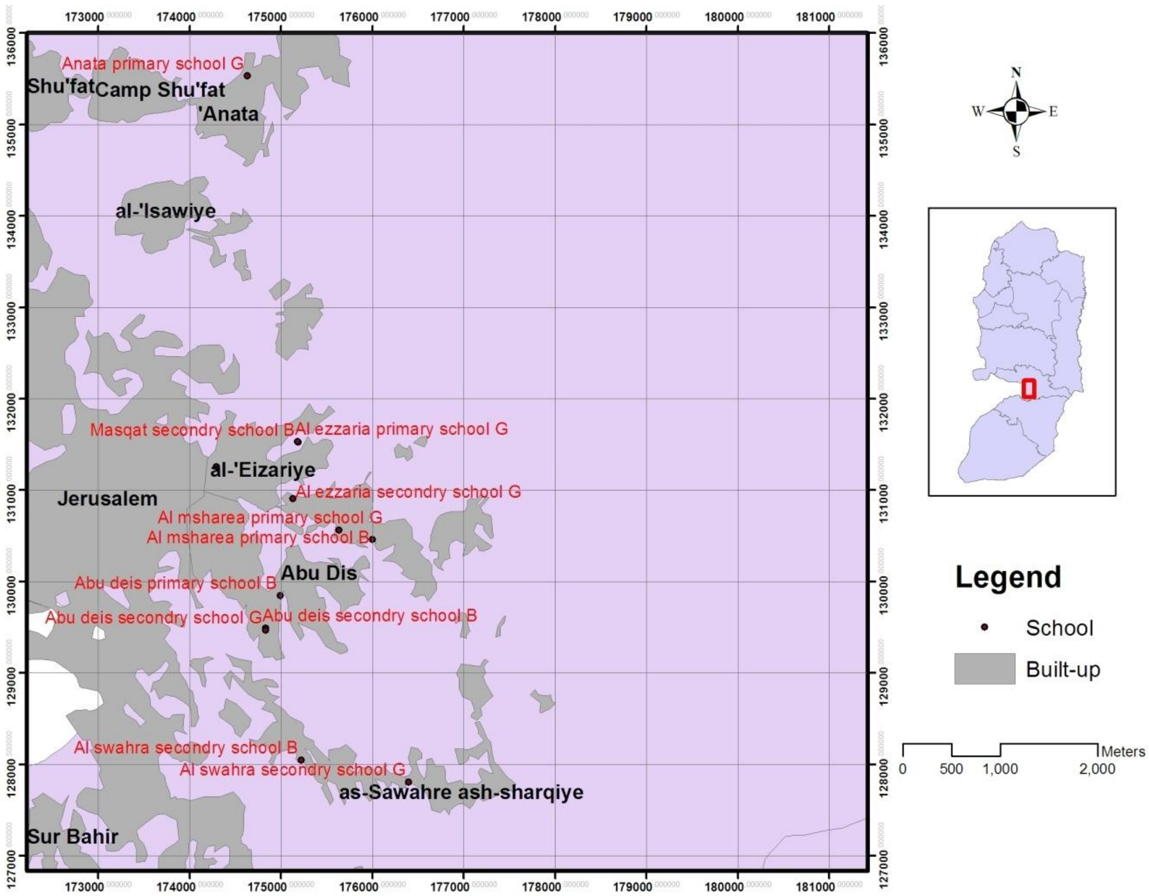


Figure 3. 5: Location of the measuring sites of the schools in East Jerusalem**.**

Other measurements were made in selected schools by following the instruction in figure (3.6).This was conducted between 6/10/09 –27/2/2010 in tables (3.3.) and (3.4).

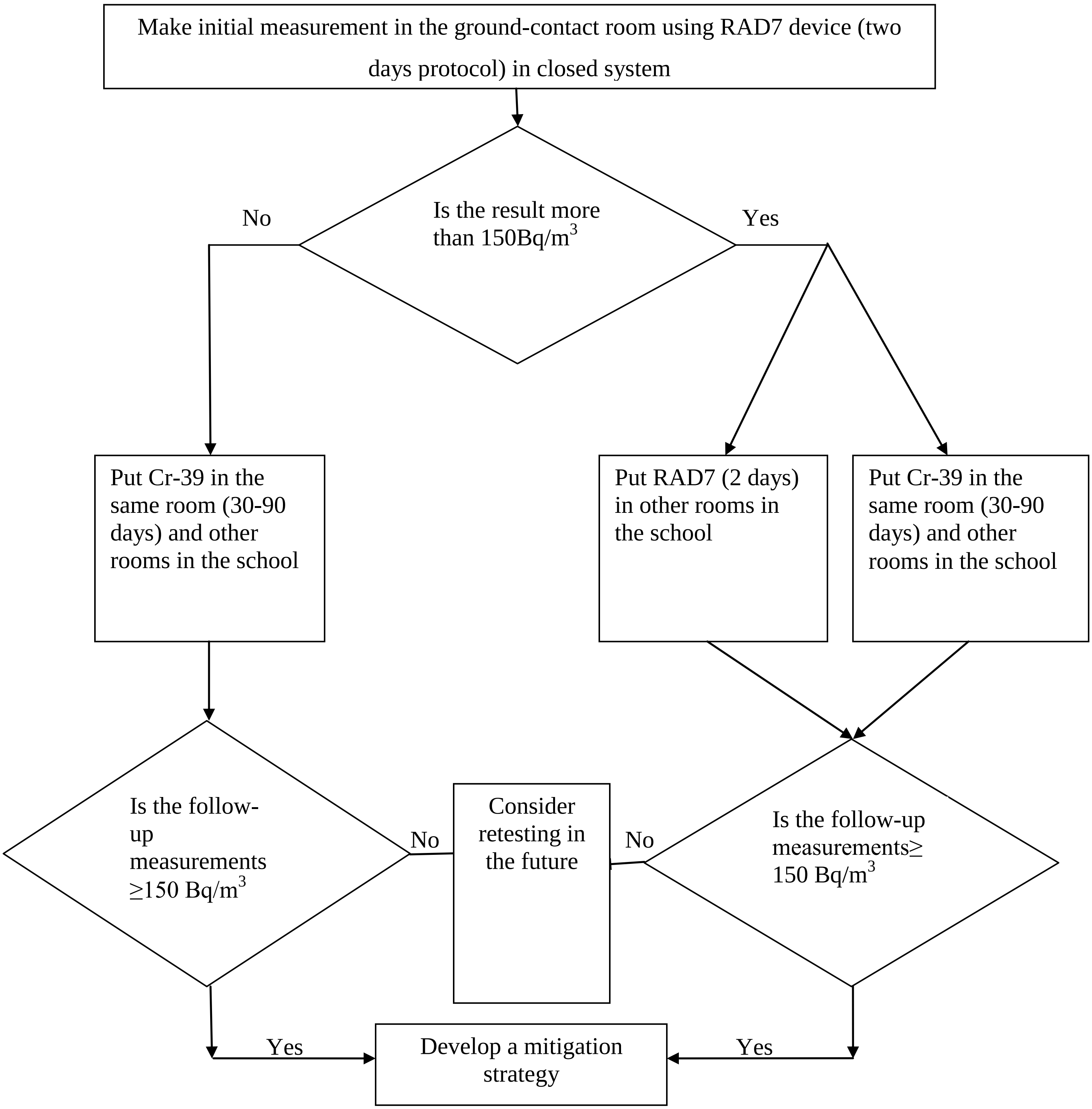


Figure 3.6: Measurement protocol.

Table 3.3 using of RAD7 detector in schools with the measuring site and the floor number on the follow up measurements.

School Name	**Measuring Site**	**Floor Number**
Al Swahreh Secondray School for girls (Al Swahereh)	Lab (1)	2
Al Swahreh Secondray School for girls (Al Swahereh)	Lab (2)	2
Al Swahreh Secondray School for girls (Al Swahereh)	Headmistress room	1
Al Swahreh Secondray School for girls (Al Swahereh)	6 class A	Basement
Al Swahreh Secondray School for girls (Al Swahereh)	7 class	Basement
Al Swahreh Secondray School for girls (Al Swahereh)	Teachers room	1
Al Masharee Primary school for boys (Al Azaria)	Headmaster room	1
Al Masharee Primary school for girls (Al Azaria)	Library	2
Al Masharee Primary school for girls (Al Azaria)	Forth class	Basement

Table 3. 4: using RAD 7 in schools within start and end date, measuring site and floor number.

School Name	Start Date	Measuring Site	End Date
Al Swahreh Secondray School for girls (Al Swahereh)	6/10/2009	Lab(1)	8/10/2009
Al Swahreh Secondray School for girls (Al Swahereh)	10/1/2010	Lab(2)	12/1/2010
Al Swahreh Secondray School for girls (Al Swahereh)	11/10/2009	Headmistress Room	13/10/2010
Al Swahreh Secondray School for girls (Al Swahereh)	15/10/2009	7th Class	17/10/2009
Al Swahreh Secondray School for girls (Al Swahereh)	8/10/2009	6th Class (A)	10/10/2009
Al Swahreh Secondray School for girls (Al Swahereh)	3/10/2009	Teachers Room	5/10/2009
Al Masharee Primary school for boys (Al Azaria)	25/10/2009	Headmistress Room	27/10/2009
Al Masharee Primary school for girls (Al Azaria)	31/1/2010	Library	2/2/2010
Al Masharee Primary school for girls (Al Azaria)	25/2/2010	Forth class	27/2/2010

Passive Radon detectors Cr-39 were distributed in the schools for a period range between 30-90 days,

Figures (3.7) and (3.8) presented the Cr-39 detectors site in Jericho and Hebron cities.

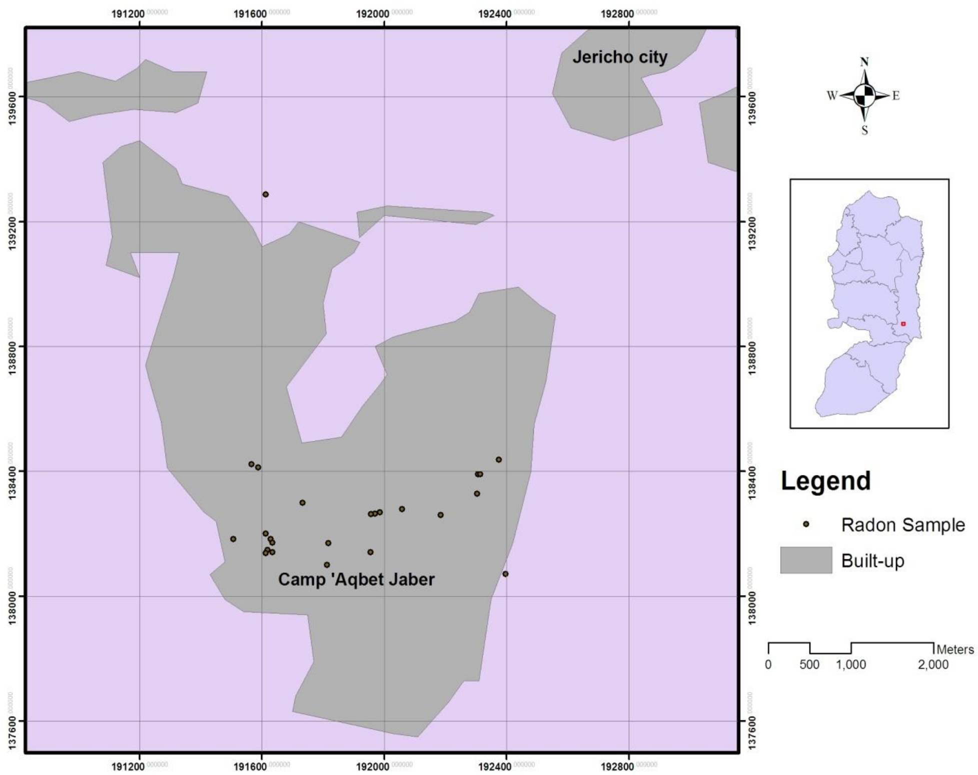


Figure 3. 7: location of the distributed detectors (Cr-39) in Aqabet Jaber (Jericho).

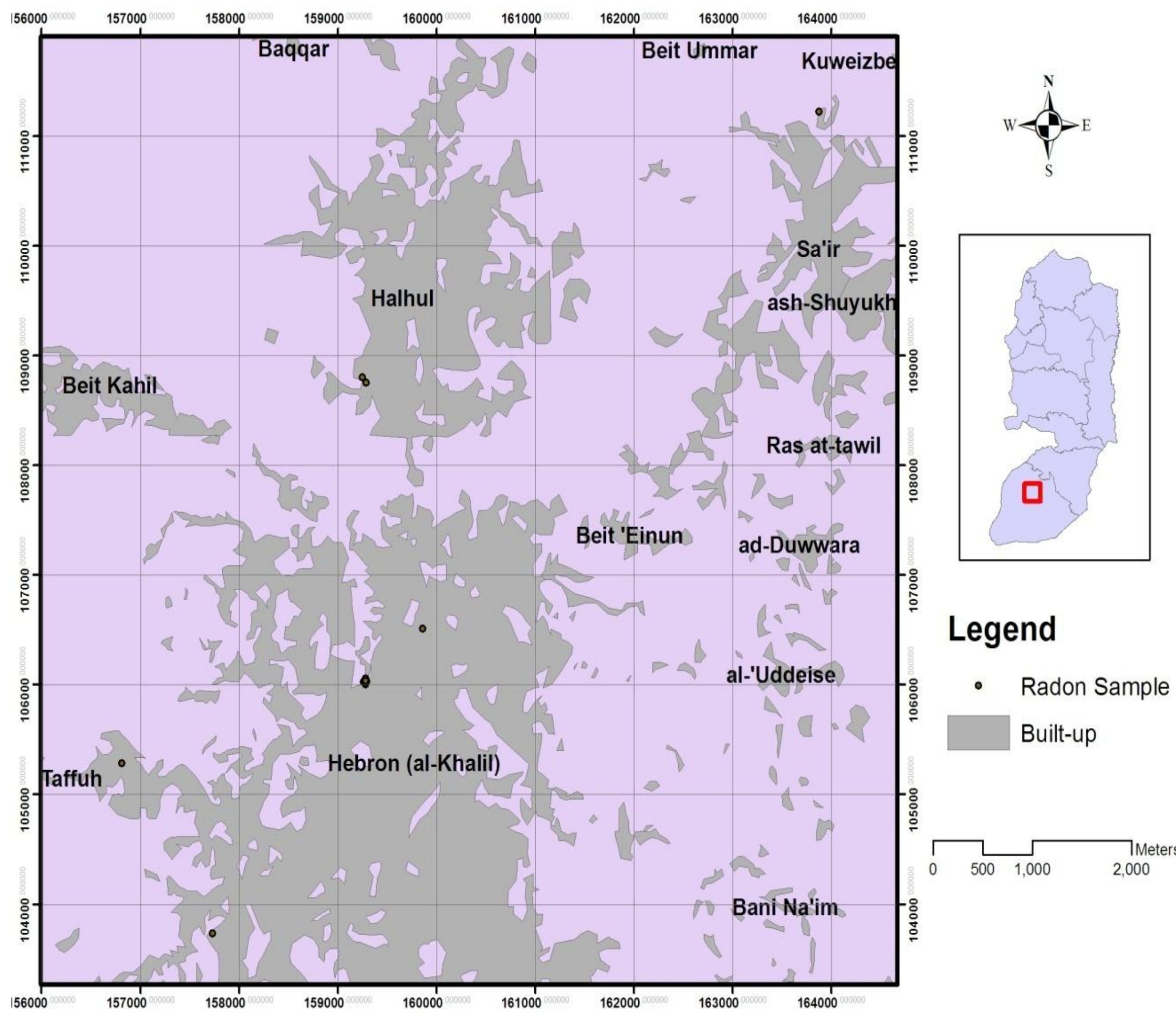


Figure 3. 8: Location of the distributed Cr-39 detectors in Hebron Area.

Figure (3, 9) shows Cr-39 detector hanged on the wall measuring ^{222}Rn concentration.

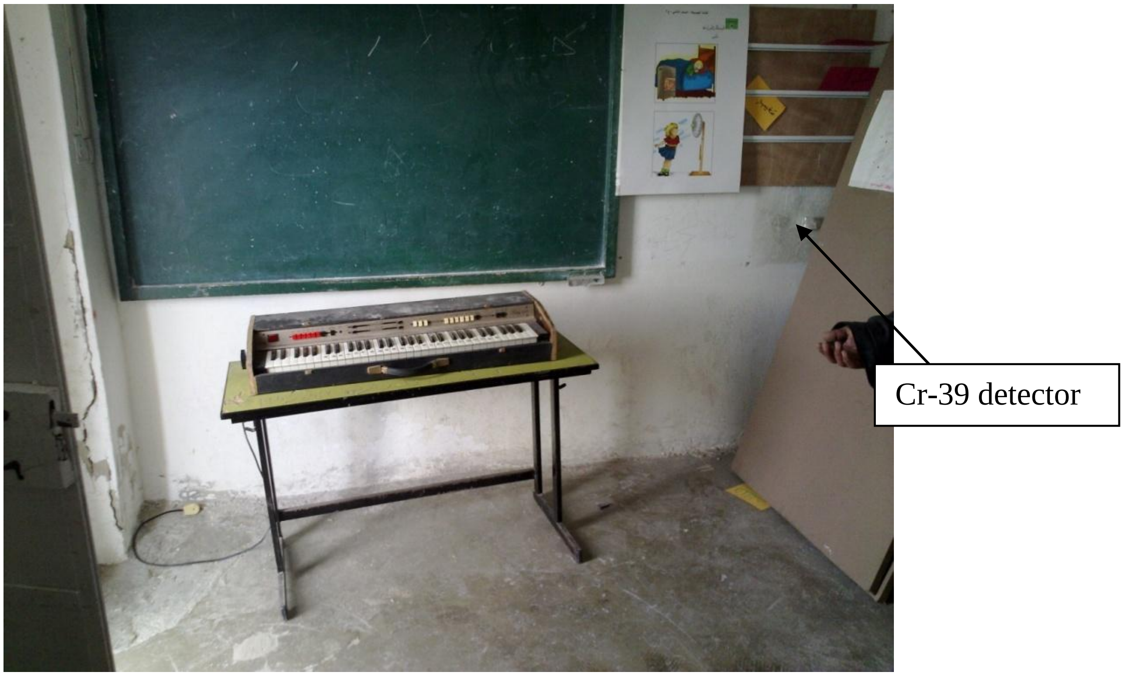


Figure 3. 9: A classroom of Al- Masharee boys school shows Cr-39 detector was hanged on the wall.

Details information about the locations of Cr-39 in the schools, with the date of construction time, measuring sites and the number of the floor in Abu Dis, Al-Azaria, and Al-Swahereh schools are shown in the table (3.5,a,b and c).

Table 3. 5.a: The distribution of Cr-39 in schools in Abu Dis, Al-Azaria, and Al-Swahereh schools with the date of construction and measuring site and the floor number.

School Name	Date of Construction	Measuring Site	Floor
Yusef Al Kateeb Primary School for Boys (Al azaria)	1948	Head Master Room	2
		Teacher Rooms	2
		Secretary Room	2
Al Masharee Primary School for Girls(Al azaria)	1976	Headmistress Room	2
		Teachers Room	2
Al Masharee Primary School for Boys(Al azaria)	1971	Headmaster Room	1
		Teachers Room	1
		Library	1
		Second Class	Basement
Al Azaria Primary School for Girls (Al azaria)	1936	Teachers Room	1
		Headmistress Room	1
Al Azaria Secondary School for Girls(Al azaria)	1990	Headmistress Room	1
		10^{th} Class Room	1
		8^{th} Class	1
		11^{th} Grade Class Room	1
		11^{th} Grade Class Room	1
		Computer Room	1

Table 3.5.b: The distribution of Cr-39 in schools in Abu Dis, Al-Azaria, and Al-Swahereh schools with the date of construction and measuring site and the floor number.

School Name	Date of Construction	Measuring Site	The Floor Number
Abu Dis Primary School for Boys (Abu Dis)	1983	First Class	1
		Second Class A	1
		Second Class B	1
		First Class	1
		Teachers Room	1
		Headmistress Room	1
		Library	1
		Fourth Class	2
Abu Dis Secondary School for Girls (Abu Dis)	1997	Theatre1	Basement
		Theatre	Basement
		Stairs	Basement
		Class Grade11	1
		Vocational Room	1
		Teachers Room	1
		Art Room	1
		Computer Room	1
		12 Grad Room	2
		Headmistress Room	1
		Secretary Room	1
		Store Room	1
		Supervisor Room	1
Abu Dis Secondary School for Boys(Abu Dis)	1950	Secretary Room	2
		Teachers Room	2
		Supervisor Room	2
		Kitchen Room	2
Al Swahreh Secondary School for Boys (Al Sawahereh)	1937	Headmistress Room	1
		Supervisor Room	1
		Teachers Room	1

Table 3.5.c: The distribution of Cr-39detectors in schools in Abu Dis, Al-Azaria, and Al-Swahereh schools with the date of construction and measuring site and the floor number.

School Name	**Date of Construction**	**Measuring Site**	**The Floor Number**
Al Swahreh Secondary School for Girls (Al Sawahereh)	1965	Teachers Room	1
		6^{th} Grade B	Basement
		5^{th} Grade A	2
		Laboratory	2
		10^{th} Grade B	1
		12^{th} Grade	1
		5^{th} Grade B	2
		7^{th} Grade	Basement
		9^{th} Grade	1
		11^{th} Grade	1
		Library	3
		Headmistress Room	1
		Six Grade A	Basement
Maskat Secondary School for Boys (Al aizari)	2007	Secretary Room	1
		Headmaster Room	1
		Teachers Room	1
		12^{th} Grade Class Room	2
		Computer Room	1
		Supervisor Room	1

Tables (3.6) and (3.7) presented the distributed of Cr-39 detectors in schools with measuring site, date of construction time, and the floor number in Jericho and Hebron cities.

Table 3.6: Cr-39 detectors in schools with measuring site date of construction time, and the floor number in Jericho schools.

School Name	Date of Construction	Measuring Site	The Floor Number
Aqabet Jaber School for Girls (Jericho)	2007	Head mistress room	1
		Kitchen	1

Table 3.7: Cr-39 detectors in schools with measuring site, date of construction, and the floor number in Hebron schools.

School Name	Date of Construction	Measuring Site	The Floor Number
Salah School for Boys (Hebron)	2005	Headmaster room	1
		Teachers room	1
		Lab	1
Halhool School for Girls (Hebron)	1997	First class	1
		Teachers room	1
		Headmaster room	1
		Supervisor room	1
		Lab	1

Details about distributed of Cr-39 detectors in Jericho with the measuring sites, and the floor number in table (3.8).

Table 3.8 Distributed of Cr-39 detectors, with the measuring sites and the floor number in Jericho.

Location	**Measuring Site**	**The Floor Number**
1	Head Mistress Room	1
2	Sitting Room	1
3	Sitting Room	1
4	Sitting Room	2
5	Store	1
6	Shop	1
7	Store	1
8	Store	1
9	Store	1
10	Sitting Room	2
11	Sitting Room	1
12	Sitting Room	1
13	Sitting Room	1
14	Sleeping Room	2
15	Sitting Room	3
16	Shop	1
17	Sleeping Room	1
18	Kitchen	1
19	Sleeping Room	1
20	Shop	1
21	Mosque for Men	1
22	Mosque for Women	2
23	Sitting Room	1
24	Shop	1
25	Head Mistress Room	1

Table (3.9). Shows the distributed of Cr-39detectors in Hebron with the measuring sites, and the floor number.

Table 3.9: Distributed of Cr-39 detectors, with the measuring sites and the floor number in private houses in Hebron.

Location	**Measuring Site**	**The Floor Number**
1	Sitting room	1
2	Sitting room	1
3	Sitting room	1
4	Sleeping room	1
5	Sleeping room	1
6	Sitting room	1
7	Sitting room	1
8	Sitting room	1
9	Sleeping room	2
10	Store	1
11	Sleeping room	2
12	Sitting room	1
13	Sitting room	1

Cr-39 detectors distributed and collected dates were presented in tables bellow

Table.3.10.a: Cr-39 detectors with distributed and collected dates in schools in Abu Dis, Al-Azaria, and Al-Swahereh.

School Name	Measuring Site	First Date	End Date
Yusef Al Kateeb Primary School for Boys (Al Azaria)	Head Mistress	29/7/2009	13/10/2009
	Teacher Rooms	29/7/2009	13/10/2009
	Secretary Room	29/7/2009	13/10/2009
Al Masharee Primary School for Girls (Al Azaria)	Headmistress Room	29/7/2009	3/11/2009
	Teachers Room	29/7/2009	3/11/2009
Al Masharee Primary School for Boys (Al Azaria)	Headmistress Room	29/7/2009	3/11/2009
	Teachers Room	29/7/2009	3/11/2009
	Library	29/7/2009	3/11/2009
	Second Class	29/7/2009	3/11/2009
Al Azaria Primary School for Girls (Al Azaria)	Headmistress Room	29/7/2009	6/10/2009
	Teachers Room	29/7/2009	6/10/2009
	Teachers Room	29/7/2009	6/10/2009
Al Azaria Secondary School for Girls (Al Azaria)	Headmistress	22/7/2009	6/10/2009
	10^{th} Class Room	22/7/2009	30/8/2009
	8^{th} Class	22/7/2009	30/8/2009
	11^{th} Grade Class Room	22/7/2009	30/8/2009
	11^{th} Grade Class Room	22/7/2009	30/8/2009
	Computer	22/7/2009	30/8/2009

Table 3.10.b: Cr-39 detectors with distributed and collected dates in schools in Abu Dis, Al-Azaria, and Al-Swahreh.

School Name	Measuring site	first date	end date
Abu Dis Primary School for Boys (Abu Dis)	First Class	22/7/2009	30/8/2009
	Second Class A	22/7/2009	30/8/2009
	Second Class B	22/7/2009	30/8/2009
	First Class	22/7/2009	30/8/2009
	Teachers Room	22/7/2009	6/10/2009
	Headmistress Room	22/7/2009	6/10/2009
	Library	22/7/2009	30/8/2009
	Fourth Class	22/7/2009	30/8/2009
Abu Dis Secondary School for Girls (Abu Dis)	Theatre	22/7/2009	30/8/2009
	Theatre	22/7/2009	30/8/2009
	Stairs	22/7/2009	30/8/2009
	Class Grade11	22/7/2009	30/8/2009
	Vocational Room	22/7/2009	30/8/2009
	Teachers Room	22/7/2009	6/10/2009
	Art Room	22/7/2009	30/8/2009
	Computer	22/7/2009	30/8/2009
	12 Grad Room	22/7/2009	30/8/2009
	Headmistress Room	22/7/2009	30/8/2009
	Secretary Room	22/7/2009	6/10/2009
	Store Room	22/7/2009	6/10/2009
	Supervisor Room	22/7/2009	6/10/2009
Abu Dis Secondary School for Boys (Abu Dis)	Secretary Room	30/8/2009	3/11/2009
	Teachers Room	30/8/2009	3/11/2009
	Supervisor Room	30/8/2009	3/11/2009
	Kitchen Room	30/8/2009	3/11/2009
Al Swahreh Secondary School for Boys (Al Swahreh)	Headmistress Room	29/7/2009	3/11/2009
	Supervisor Room	29/7/2009	3/11/2009
	Teachers Room	29/7/2009	3/11/2009

Table 3.10.c: Cr-39 detectors with distributed and collected dates in schools in Abu Dis, Al-Azaria, and Al-Swahereh.

School Name	Measuring site	First Date	End date
Al Swahreh Secondary School for Girls (Al Swahereh)	Teachers Room	13/9/2009	1/12/2009
	6th Grade B	13/9/2009	1/12/2009
	5th Grade A	13/9/2009	1/12/2009
	Laboratory	13/9/2009	1/12/2009
	10th Grade B	13/9/2009	1/12/2009
	12th Grad	13/9/2009	1/12/2009
	5th Grade B	13/9/2009	1/12/2009
	7th Grade	13/9/2009	1/12/2009
	9th Grade	13/9/2009	1/12/2009
	11th Grade	13/9/2009	1/12/2009
	Library	13/10/2009	1/12/2009
	Headmistress Room	13/10/2009	1/12/2009
	Six Grade A	13/9/2009	1/12/2009
Maskat Secondary School for Boys (Al Azaria)	Secretary Room	22/7/2009	3/11/2009
	Headmistress Room	22/7/2009	3/11/2009
	Teachers Room	22/7/2009	3/11/2009
	12th Grade Class Room	22/7/2009	30/8/2009
	Computer Room	22/7/2009	30/8/2009
	Supervisor Room	22/7/2009	3/11/2009

Table 3.11: Jericho schools within first and end date of distributed and collected dates of the Cr-39 detectors.

School Name	**Measuring Site**	**First date**	**End date**
Aqubet Jaber School for Girls (Jericho)	Head Mistress Room	26/10/2009	12/12/2009
	Kitchen	26/1020/09	12/12/2009

Table 3.12: Hebron schools within first and end date of distributed and collected dates of the Cr-39 detectors.

School Name	**Measuring Site**	**First date**	**End date**
Salah School for Boys (Hebron)	Headmaster room	28/10/2009	28/12/2009
	Teachers room	28/10/2009	28/12/2009
	Lab	28/10/2009	28/12/2009
Halhool School for Girls (Hebron)	First class	11/10/2009	28/12/2009
	Teachers room	11/10/2009	28/12/2009
	Headmistress room	11/10/2009	28/12/2009
	Supervisor room	27/10/2009	28/12/2009
	Lab	31/8/2009	28/12/2009

Table 3.13: Jericho dwellings within first and end date of distributed and collected dates of the Cr-39 detectors.

Location	**Measuring Site**	**First Date**	**End Date**
1	Head mistress room	26/10/09	12/12/2009
3	Sitting room	26/10/09	12/12/2009
4	Sitting room	26/10/09	12/12/2009
5	Sitting room	26/10/09	12/12/2009
6	Store	26/10/09	12/12/2009
7	Shop	26/10/09	12/12/2009
8	Store	26/10/09	12/12/2009
9	Store	26/10/09	12/12/2009
10	Store	26/10/09	12/12/2009
11	Sitting room	26/10/09	12/12/2009
12	Sitting room	26/10/09	12/12/2009
13	Sitting room	26/10/09	12/12/2009
14	Sitting room	26/10/09	12/12/2009
15	Sleeping room	26/10/09	12/12/2009
18	Sitting room	26/10/09	12/12/2009
19	Shop	26/10/09	12/12/2009
21	Sleeping room	26/10/09	12/12/2009
22	Kitchen	26/10/09	12/12/2009
23	Sleeping room	26/10/09	12/12/2009
24	Shop	26/10/09	12/12/2009
25	Mosque For men	26/10/09	12/12/2009
26	Mosque For women	26/10/09	12/12/2009
28	Sitting room	26/10/09	12/12/2009
29	Shop	26/10/09	12/12/2009
30	Headmistress room	26/10/09	12/12/2009

Table 3.14: Private buildings in Hebron within first and end date of distributed and collected dates of the Cr-39 detectors.

Location	Measuring room	First date	End date
1	Sitting	27/10/09	28-12-2009
2	Sitting	27/10/09	28-12-2009
3	Sitting	27/10/09	28-12-2009
4	Sleeping	27/10/09	28-12-2009
5	Sleeping	27/10/09	28-12-2009
6	Sitting	27/10/09	28-12-2009
7	Sitting	27/10/09	28-12-2009
8	Sitting	27/10/09	28-12-2009
9	Sleeping	27/10/09	28-12-2009
10	Store	27/10/09	28-12-2009
12	Sleeping	28/10/09	28-12-2009
13	Sitting	16/10/09	28-12-2009
15	Sitting	11/10/2009	28-12-2009

Table 3.15: Abu Dis houses within first and end date of distributed and collected dates of the Cr-39 detectors.

Location	**The Room**	**First Date**	**End Date**
1	Sleeping Room	15/8/09	13/12/09
2	Sleeping Room	25/9/2009	13/12/2009
3	Store	12/10/2009	6//1/2010

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3.4: Analysis of Cr-39 detectors

121 detectors Cr -39 were collected from the schools and other private buildings, 25 detectors were lost. The collected detectors were taken out from the plastic cups, and prepared for chemical etching in 6.25M NaOH solution at 70^{o} C temperature for 4.5 hours, (Dabaynah,and Awawdeh,2007),then the detectors were rinsed with distilled water, and dried .The tracks were counted using an optical microscope with magnification of 200X to calculate the track density. Figure (3.10) below shows the track densities.

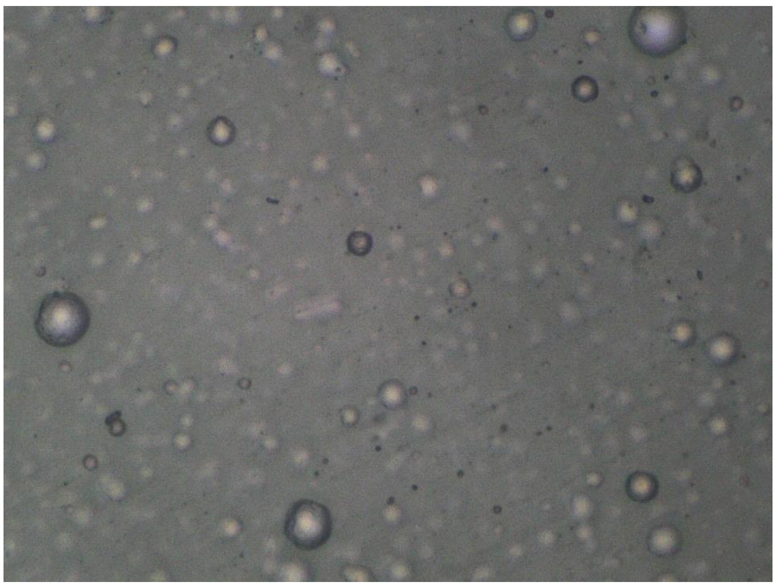

Figure 3. 10: shows the track densities by optical microscope.

The Cr-39 Radon detector was calibrated in a standard source facility at the NRPB (National Radiological Protection Board), UK (Dabayneh, 2006).

Ten fields of view were selected at random for each detector. The size of each field of view at 200X magnification was obtained. The counts obtained for all of views were averaged and converted into account $/cm^2$. The obtained track density can be converted to Radon concentration, C_{Rn} (in Bq/m^3) using the calibration factor of the element according to the following equation:

$$C\ (Rn) = \frac{C_0 t_0 d}{d_0 t} \tag{3.1}$$

Where C_0 (90 KBq/m^3) is the radon concentration in calibration chamber (Awawdeh, 2001), t_0 (48hours) is the exposure of detector in radon chamber; d is the density of nuclear tracks measured in units of tracks/cm^2 , d_0 is equals to 3.3 x 10^4; the nuclear track density measured after its calibration , and t is the exposure time in the experiment (Shehadeh,2008).
The annual effective dose equivalent (D) for the individual in the homes were calculated in (mSv/yr) by the following equation (Chen, 2005; Dabayneh, 2006);

$$D = \frac{0.4 \times \frac{3.88 mSv}{WLM} \times C_{Rn} \times 7000 hr}{\frac{3700 Bq}{m^3} \times 170 h} \tag{3.2}$$

Where 0.4 is the equilibrium factor: 3.88 mSv /WLM is the International Commission on Radiological Protection (ICRP) conversion factor. WLM is the working- level month; this old unit for exposure is attained by 170 hr breathing in air in which Radon concentration of 3700 Bq/m^3.C_{Rn} is the Radon concentration in Bq/m^3. 7000 hr is the mean time t (occupancy factor 0.8) per year (~ 19 hr per day).

The annual effective dose equivalent (D) for the individual in the schools were calculated in (mSv/yr) by the following equation (Dabayneh, 2006);

$$D = \frac{0.4 \times \frac{3.88 mSv}{WLM} \times C_{Rn} \times 7000 hr}{\frac{3700 Bq}{m^3} \times 170 h \equiv} \tag{3.3}$$

The same of the equation (3.2) except the mean time t is about 1750 h instead of 7000 hr above (occupancy factor 0.2) per yr (~ 5 hr per day) at schools for pupils and staff. (Dabayneh, 2006).

Chapter IV

Results and Discussions

4. Introduction:

Indoor Radon concentration results using RAD7 and Cr-39 were presented. RAD7 was used in government schools in Al Azaria, Abu Dis and Al Sawahereh; RAD7 was left on a table in measurement place to work continuously for 48 hours in closed system. The school name, measuring site, Date of construction, floor number, equivalent dose, minimum, mean, maximum, and standard deviation of Radon concentration were presented in tables for easy view of results .Cr-39 detectors were used in the same previous schools and some buildings in Hebron and Jericho in natural system of life. Measuring site, floor number, Radon concentration and equivalent dose were presented in tables too. This work made it easy and clear to understand the results then convert it to charts for discussion in the following section.

4.1: Results of measurements by Using RAD7 Detectors

RAD7 detector was used in schools to detect the concentration of Radon gas in some dwellings and schools. Table (4.1) and (4.2) show the minimum, mean, maximum, and standard deviation of the measurements in Bq/m^3 in 13 government schools in Anata ,Al-Azaria, Abu Dis ,and Al-Swahereh areas with the annual effective dose in mSv/yr.

Table 4. 1: Indoor Radon concentration and the effective dose in the schools in East Jerusalem with floor number and date of construction**.**

School Name	**School Number**	**Measuring Site**	**Min Bq/m^3**	**Max Bq/m^3**	**Mean Bq/m^3**	**S.D Bq/m^3**	**Effective Dose mSv/yr**	**Date of Construction**	**Floor Number**
Anata Primary School	1	Pray Room	5.27	77.8	33.1	19.6	0.36	1970	1
Yusef Al Kateeb Primary School Boys	2	Physical Education	17.1	77.8	38	16	0.41	1948	2
Al Masharee Primary School Girls	3	Headmistress Room	2.64	31.7	12.7	6.19	0.14	1976	2
Al Masharee Primary School Boys	4	Second Class	60.7	442	**160**	85.8	**1.72**	1971	1
Al Azaria Primary School for Girls	5	Teachers Room	10.6	68.6	35.3	14.5	0.38	1936	1
Al Azaria Secondary School Girls	6	10th Class	16.5	131	66.8	23.8	0.72	1990	1
Abu Dis Primary School Boys(new)	7	Library	5.28	56.7	28.7	13.7	0.31	1983	1
Abu Dis Primary School Boys(old)	8	Class Room	21.1	97.6	58.5	16.6	0.63	1933	1
Abu Dis Secondary School Girls	9	Theatre	27.7	84.4	52.6	13.7	0.57	1997	Basement
Abu Dis Secondary School Boys	10	Supervisor Room	0.0	19.8	6.27	4.06	0.06	1950	2
Al Swahreh Secondary School Boys	11	Headmaster Room	1.32	22.4	9.74	5.17	0.10	1937	1
Al Swahreh Secondary School Girls	12	6th Class B	30.2	459	**324**	102	**3.49**	1965	Basement
Maskat Secondary School Boys	13	12th Class	14.5	88.4	44	20.5	0.47	2007	1

Table 4. 2: Indoor Radon concentration and the effective dose in the schools in East Jerusalem with floor number and date of construction in the follow up measurements.

School Name	**School Number**	**Measuring Site**	**Min Bq/m³**	**Max Bq/m³**	**Mean Bq/m³**	**S.D Bq/m³**	**Effective Dose(mSv/yr)**	**Date of Construction**	**Floor Number**
Al Swahreh Secondray School Girls	12	Lab(1)	3.96	84.4	34.8	15.6	0.37	1965	2
Al Swahreh Secondray School Girls	12	Lab(2)	38.4	129	86.5	21.7	0.94	1965	2
Al Swahreh Secondray School Girls	12	Headmistress Room	1.32	52.2	11.9	8.38	0.13	1965	1
Al Swahreh Secondray School Girls	12	7th Class	22	621	**408**	154	**4.40**	1965	Basement
Al Swahreh Secondray School Girls	12	6th Class (A)	85.1	1860	**1370**	430	**14.76**	1965	Basement
Al Swahreh Secondray School Girls	12	Teachers room	1.32	17.1	7.85	3.73	0.08	1965	1
Al Masharee Primary school Boys	3	Headmaster Room	2.64	22.4	10.9	4.57	0.18	1971	1
Al Masharee Primary school Girls	4	library	6.52	49.6	23	9.09	0.25	1976	2
Al Masharee Primary school Girls	4	Forth class	137	437	**280**	73.4	**2.02**	1976	Basement

4.2 Results Using Cr-39 detectors:

121 detectors Cr -39 were collected from the schools and other private buildings, 25 detectors were lost. The collected detectors were taken out from the plastic cups, and prepared for chemical etching. to calculate Radon concentration by using (3.1) equation.

The annual effective dose equivalent (D) for the individual in the homes were calculated in (mSv/yr) by (3.2) equation.

The annual effective dose equivalent (D) for the individual in the schools were calculated in (mSv/yr) by (3.3) equation.

Measurements results in schools and dwellings in all of the experiment are presented in the following tables (4.3.a, b and c) to table (4.8) showing the measuring site, floor number, Radon concentration and the effective dose for the pupils and the staff in each school in Abu Dis, Al-Azaria, Al-Swahreh,Jericho and Hebron.

Table 4.3.a: Indoor Radon concentration levels and annual effective dose in schools in Abu Dis, Al-Azaria, and Al-Swahereh by Cr-39 detector.

School Name	**Measuring Site**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose (mSv/yr)**
Yusef Al Kateeb Primary School for Boys (Al Azaria)	Headmistress Room	2	46.95	0.51
	Teachers Room	2	60.44	0.65
	Secretary Room	2	227.73	**2.45**
Al Masharee Primary School for Girls(Al Azaria)	Headmistress Room	2	21.56	0.23
	Teachers Room	2	54.12	0.58
Al Masharee Primary School for Boys (Al Azaria)	Headmaster Room	1	52.43	0.56
	Teachers Room	1	62.58	0.67
	Library	1	348.81	**3.76**
	Second Class	Basement	45.24	0.49
Al Azaria Primary School for Girls (Al Azaria)	Headmistress Room	1	99.01	**1.07**
	Teachers Room	1	207.99	**2.24**
	Teachers Room	1	59.17	0.64
Al Azaria Secondary School for Girls (Al Azaria)	Headmistress Room	1	157.03	**1.69**
	10th Class Room	1	42.06	0.45
	8th Class Room	1	246.07	**2.65**
	11th Class Room(A)	1	69.41	0.75
	11th Class Room(B)	1	26.29	0.28
	Computer Room	1	298.65	**3.22**

Table 4.3.b: Indoor Radon concentration levels and annual effective dose in schools in Abu Dis, Al-Azaria, and Al-Swahereh by Cr-39 detector.

School Name	**Measuring Site**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose mSv/yr**
Abu Dis Primary School for Boys (Abu Dis)	First Class A	1	145.12	**1.56**
	Second Class A	1	156.69	**1.69**
	Second Class B	1	47.32	0.51
	First Class B	1	88.33	0.95
	Teachers Room	1	55.3	0.6
	Headmistress Room	1	45.98	0.5
	Library	1	343.87	**3.71**
	Fourth Class	2	144.07	**1.55**
Abu Dis Secondary School for Girls (Abu Dis)	Theatre	Basement	111.47	**1.2**
	Theatre	Basement	56.79	0.61
	Stairs	Basement	71.51	0.77
	Class Grade11	1	114.62	**1.24**
	Vocational Room	1	31.55	0.34
	Teachers Room	1	52	0.56
	Art Room	1	308.12	**3.32**
	Computer Room	1	163	**1.76**
	12 Grad Room	2	96.75	1.04
	Headmistress Room	1	49.07	0.53
	Secretary Room	1	49.8	0.54
	Store Room	1	269.51	**2.9**
	Supervisor Room	1	78.7	0.85
Abu Dis Secondary School for Boys (Abu Dis)	Secretary Room	2	44.17	0.48
	Teachers Room	2	105.37	**1.14**
	Supervisor Room	2	130.61	**1.41**
	Kitchen Room	2	42.9	0.46
Al Swahreh Secondary School for Boys (Al Sawahreh)	Headmaster Room	1	49.05	0.53
	Supervisor Room	1	35.52	0.38
	Teachers Room	1	45.24	0.49

Table 4.3.c: Indoor Radon concentration levels and annual effective dose in schools in Abu Dis, Al-Azaria, and Al-Swahereh by Cr-39 detector.

School Name	**Measuring site**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose mSv/yr**
Al Swahreh Secondary School for Girls (Al Swahreh)	Teachers Room	1	34.7	0.37
	6th Grade B	Basement	60.66	0.65
	5th Grade A	2	38.33	0.41
	Laboratory	2	42.06	0.45
	10th Grade B	1	34.7	0.37
	12th Grad	1	31.55	0.34
	5th Grade B	2	29.44	0.32
	7th Grade	Basement	49.95	0.54
	9th Grade	1	45.22	0.49
	11th Grade	1	48.37	0.52
	Library	3	36.28	0.39
	Headmistress Room	1	64.94	0.7
	Six Grade A	Basement	45.22	0.49
Maskat Secondary School for Boys (Al Azaria)	Secretary Room	1	145.12	**1.56**
	Headmistress Room	1	36.67	0.4
	Teachers Room	1	278.8	**3**
	12th Grade Class Room	2	94.64	**1.02**
	Computer Room	1	98.85	**1.07**
	Supervisor Room	1	63.49	0.68

Table 4.4: Indoor Radon concentration levels and annual effective dose by Cr-39 detector in Jericho schools.

School Name	Construction Time	Measuring Site	Floor Number	^{222}Rn Bq/m^3	Effective Dose (mSv/yr)
Aqubet Jaber School for Girls(Jericho)	2007	Headmistress Room	1	28.8	0.31
		Kitchen	1	90.75	0.98

Table 4.5: Indoor Radon concentration levels and annual effective dose by Cr-39 detector in Hebron schools.

School Name	Construction Time	Measuring Site	Floor Number	^{222}Rn Bq/m^3	Effective Dose (mSv/yr)
Salah School for Boys (Hebron)	2005	Headmaster room	1	92.44	**1**
		Teachers room	1	113.92	**1.23**
		Lab	1	63.8	0.69
Halhool School for Girls (Hebron)	1997	First class	1	79.42	0.86
		Teachers room	1	188.66	**1.95**
		Headmistress room	1	11.94	0.13
		Supervisor room	1	74.76	0.81
		Lab	1	25.42	0.27

Table 4.6: Indoor Radon concentration levels and annual effective dose by Cr-39 detector Jericho buildings with the effective dose.

Location	**Measuring Site**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose (mSv/yr)**
1	Headmaster Room	1	110.82	**1.92**
2	Sitting Room	1	277.49	**4.8**
3	Sitting Room	1	37.52	0.65
4	Sitting Room	2	289.7	**5.01**
5	Store	1	139.62	**2.42**
6	Shop	1	406.63	**7.03**
7	Store	1	444.15	**7.68**
8	Store	1	101.22	**1.75**
9	Store	1	71.55	1.24
10	Sitting Room	2	76.79	**1.33**
11	Sitting Room	1	124.78	**2.16**
12	Sitting Room	1	137.87	**2.39**
13	Sitting Room	1	335.95	**5.81**
14	Sleeping Room	2	465.97	**8.06**
15	Sitting Room	3	80.28	**1.39**
16	Shop	1	358.64	**6.2**
17	Sleeping Room	1	66.32	1.15
18	Kitchen	1	86.18	**1.49**
19	Sleeping Room	1	140.27	**2.43**
20	Shop	1	134.38	**2.32**
21	Mosque for Men	1	109.95	**1.9**
22	Mosque for Women	2	68.06	1.18
23	Sitting Room	1	48.87	0.85
24	Shop	1	48.87	0.85
35	Head Mistress Room	1	114.31	**1.98**

Table 4.7: Indoor Radon concentration levels and annual effective dose by Cr-39 detector Hebron private buildings.

Location	**Measuring Site**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose (mSv/yr)**
1	Sitting Room	1	76.17	**1.32**
2	Sitting Room	1	35.8	0.62
3	Sitting Room	1	55.33	0.96
4	Sleeping Room	1	58.59	1.01
5	Sleeping Room	1	227.58	**3.94**
6	Sitting Room	1	97.65	**1.69**
7	Sitting Room	1	114.57	**1.98**
8	Sitting Room	1	59.24	1.02
9	Sleeping Room	2	53.38	0.92
10	Store	1	70.96	1.23
11	Sleeping Room	2	47.52	0.82
12	Sitting Room	1	32.49	0.56
13	Sitting Room	1	32.26	0.56

Table 4.8: Indoor Radon concentration levels and annual effective dose by Cr-39 detector Abu Dis houses.

The House	**The Room**	**Floor Number**	**^{222}Rn Bq/m^3**	**Effective Dose (mSv/yr)**
1	Sleeping Room(1)	1	24	0.42
2	Sleeping Room(2)	1	20.36	0.35
3	Store	1	31.2	0.54

4.3: Discussion

4.3.1: Introduction

In this section of the study, I discussed the results of measurements obtained at schools and residential places in the study- area, using RAD7 and Cr-39 detectors. I analyzed these results, which showed the correlation between indoor Radon concentrations with pertinent variables, including elevation, date of structure construction, and, time of measurement hours.

4.3.1.1: Indoor Radon Concentrations Results.

The data which was obtained in table (4.1) in this chapter are shown in figure (4.1) the Radon concentration with the school number.

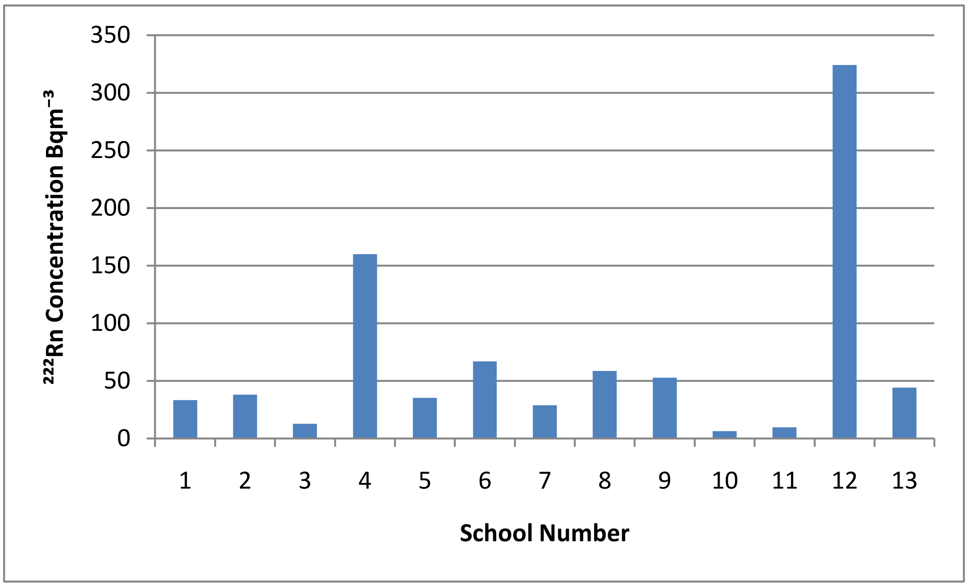

Figure 4. 1: Radon concentration in schools in the first measurements by RAD7 in schools in East Jerusalem.

There are two high levels in school number 4, and 12, I think the concentration was exceeded the recommended level in school number (12), resulted from the wall cracks. At the same time school number (4) had high concentration because the measurement was taken in the basement.

Radon source in the air of the rooms was related to the natural origin, where all schools were built above Abu Dis formation. Abu Dis formation over laid Wadi Al Quilt formation which contains phosphate and chert, both layers contains traces of Uranium One of the products of Uranium is Radon .The low Radon concentrations in the majority of these schools were related to the good air ventilation as well as to the sealing of the basements floor from where Radon could release.

Another measurements were made in these two schools, three measurements increased the acceptable value. Figure (4.2) shows indoor Radon concentration

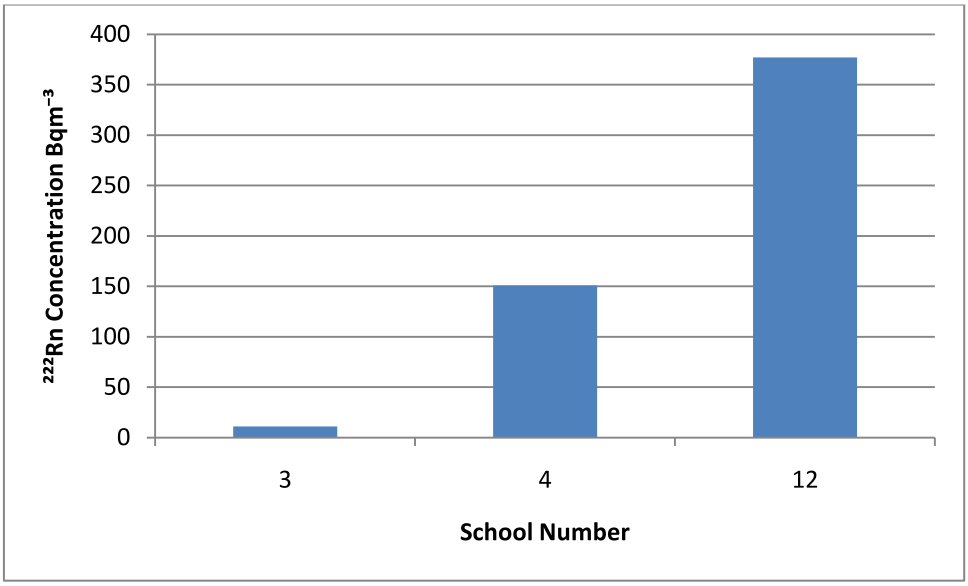

Figure 4.2: Mean Radon concentration on the second measurements by RAD7 in schools.

Figure (4.3) was performed the correlation between Radon concentration and the year of construction; there is no obvious relationship between Radon concentration and the year of construction. The age of the building is related with the kind of material used in construction and the buildings techniques.

Old schools which were built between (1933-1950) had more thickness wall than the others (Arabic Built) which prevented the entry of Radon, and the recent schools (1980-2007) had modern building techniques specially the way of ventilation which prevents Radon entry also.

The schools that built between (1965-1975) had cracks and high permeation to let Radon entry in the buildings.

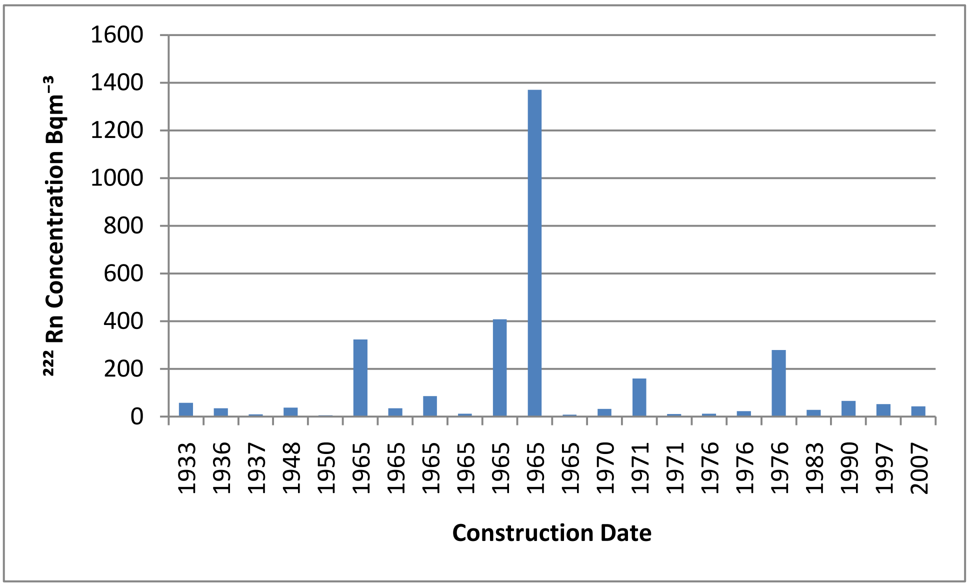

Figure 4. 3: chart of RAd7 concentration and year of construction in schools.

4.4.1: RAD7 and Cr-39 measurements in schools with floor number.

Figure (4.4) ad (4.5) explains the relationship between the availability of Radon to the earth as we go higher the gas concentration decreases and the visa versa .as you go down you find more Radon that means, as you go down you can find more Radon concentration , this related to the cracks within the basement.

The concentration is high in the basement: but it's low in the first and second floor because it was easy for the gas to enter from the soil to the nearby places.

Figure (4.5) shows that the concentrations in Al Sawahereh' school (No 12) were very high its mean reached 1370Bq/m^3 in spite of that Al Masharee' primary school(No 4) exceeded the recommended level by the concentrations in the class rooms were higher than other rooms.

Both schools were built over Wadi El Quilt formation, that consists of chert (silica) units This units contains phosphate with Uranium mineral which is the source of Radon in air.(Shirav, and Vulkan, 1997).

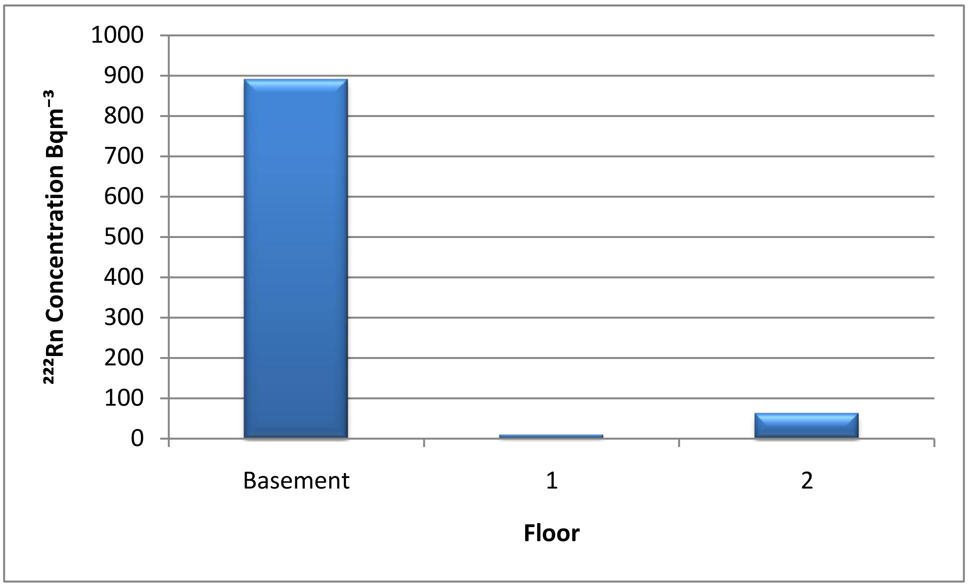

Figure 4. 4: Radon concentration and floor number in Al Swahreh school for girls measured by RAD7.

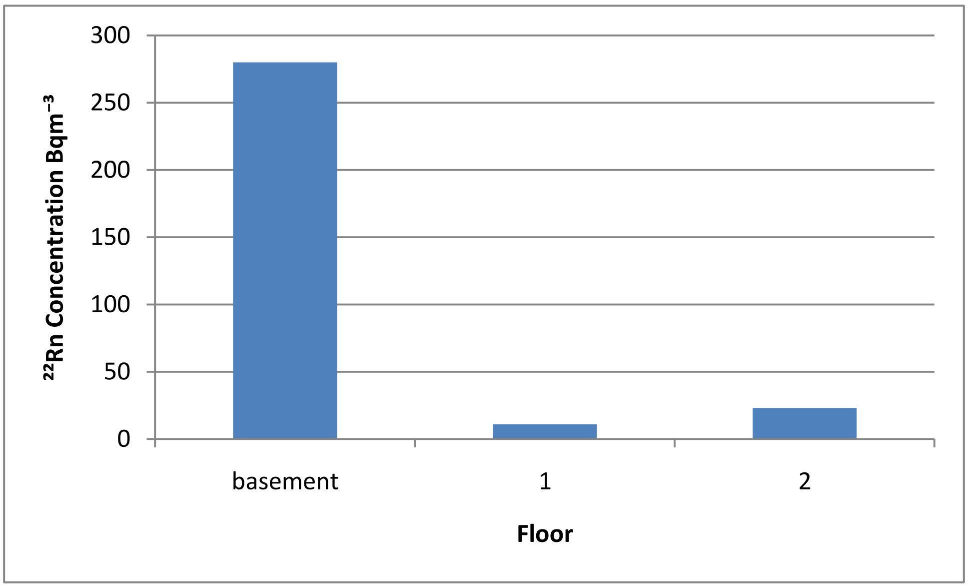

Figure 4. 5: Radon concentration and floor number in Al Masharee'school measured by RAD7.

Figure (4.6) shows all measurements in schools with the floor number by RAD7.Radon concentration is high in the basement. Figure (4.7) shows measurements in schools with the floor number by Cr-39, Radon concentration was found high into the first.

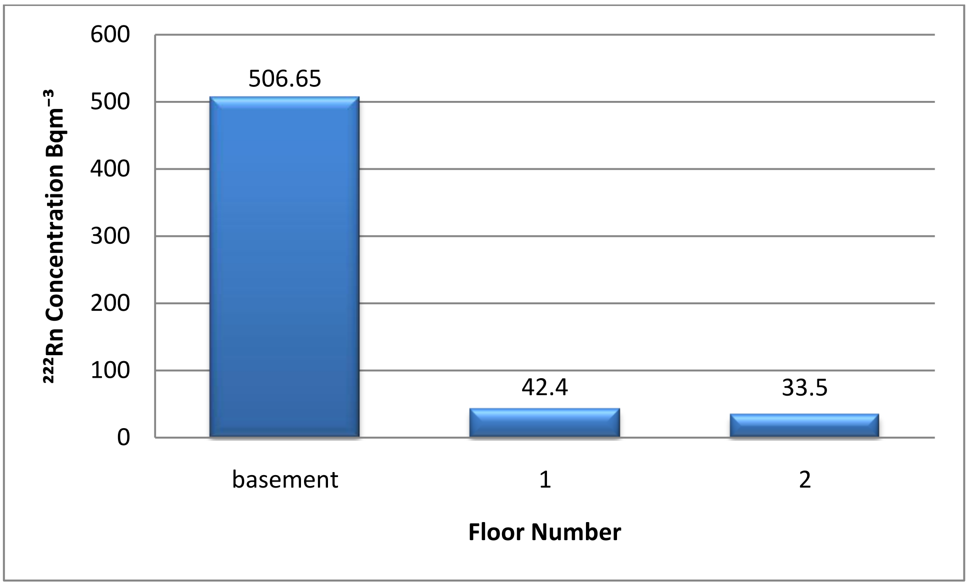

Figure 4. 6: Radon concentration and floor number in schools in all measurements by RAD7.

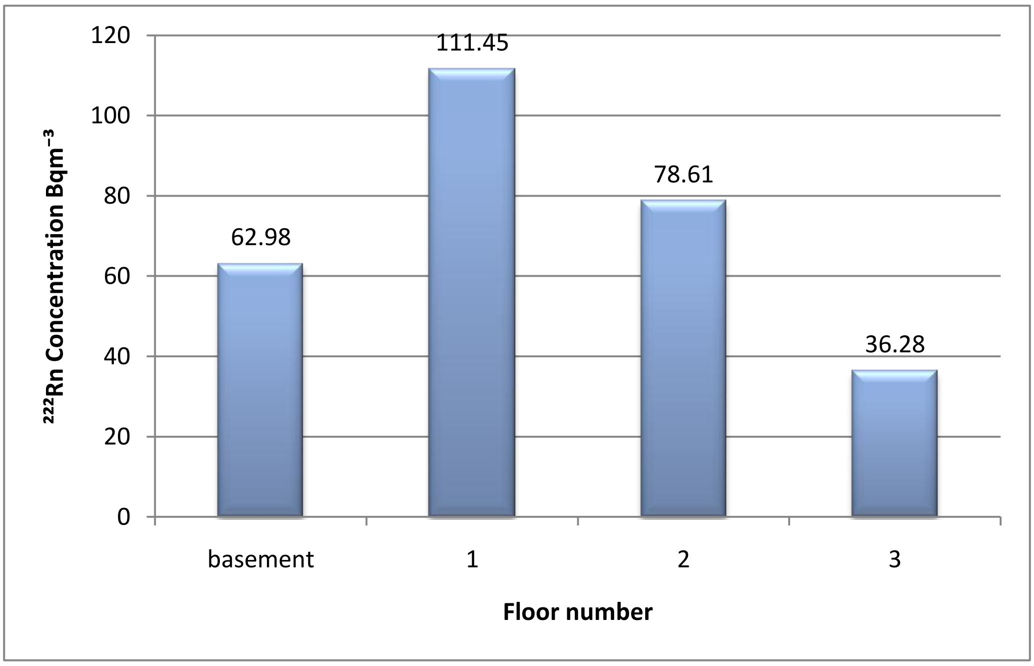

Figure 4. 7: Radon concentration and floor number in all measurements in schools by Cr-39.

High levels of Radon concentration were found in the first floor, where Radon can enter easily from the soil to the dwellings.

4.4.2: Cr-39 measurements in Abu Dis houses.

Two old houses and store place were measured by Cr-39 for long period it gives low concentrations figure (4.8).

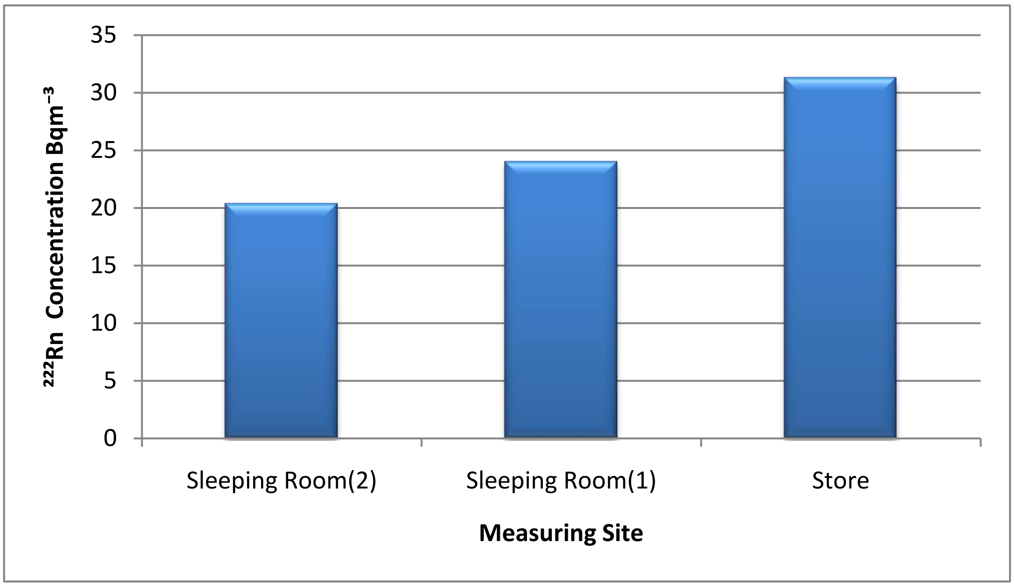

Figure 4. 8: Radon concentration in three places in Abu Dis by Cr-39.

4.4.3: Radon concentration in Anata Primary School by using Rad7

The measurement was carried out in the pray room in Anata school by RAD7 in closed system the mean concentration is 33.1 Bq/m^3 the level of Radon concentration in Anata school is low and does not exceed the recommended levels.

4.4.4: Results in Yusef Al Kateeb Primary School.

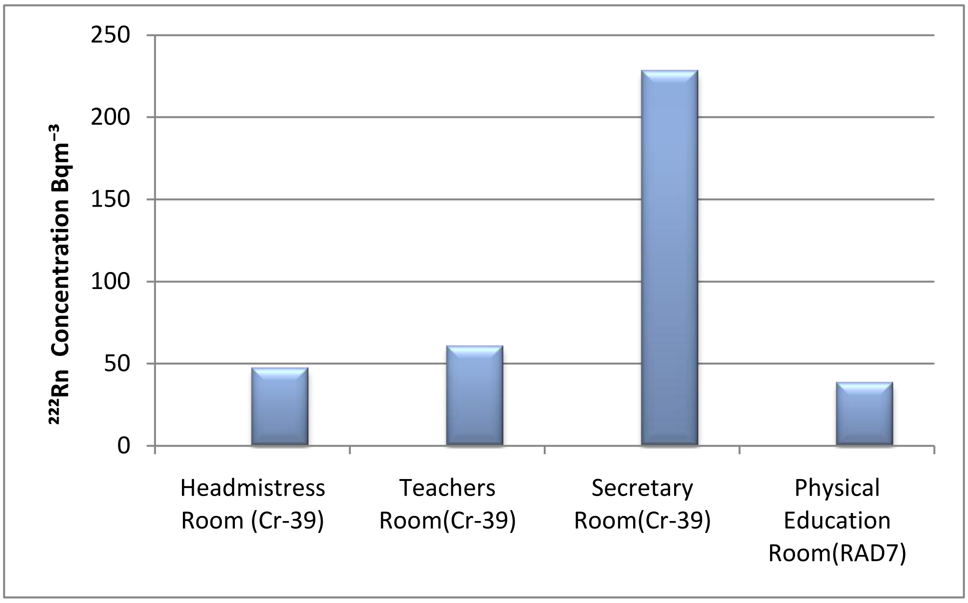

Figure 4. 9: Radon concentration and measuring site in Yousef Al Kateeb Primary Boys School by the two detectors.

The level of Radon concentration in Yuosef Al Kateeb Primary Boys School by RAD7 is very low and not exceeds recommended level; the measurements were carried out in the physical Education room which cited in the first floor, the room is good sealed.

The other measurements were taken by Cr-39 detectors the concentration in secretary room exceeded the recommended levels this due to poor ventilation; but the levels in the other rooms are low.

4.4.5:Rad7 Results in Al Swahereh Secondary Girls School.

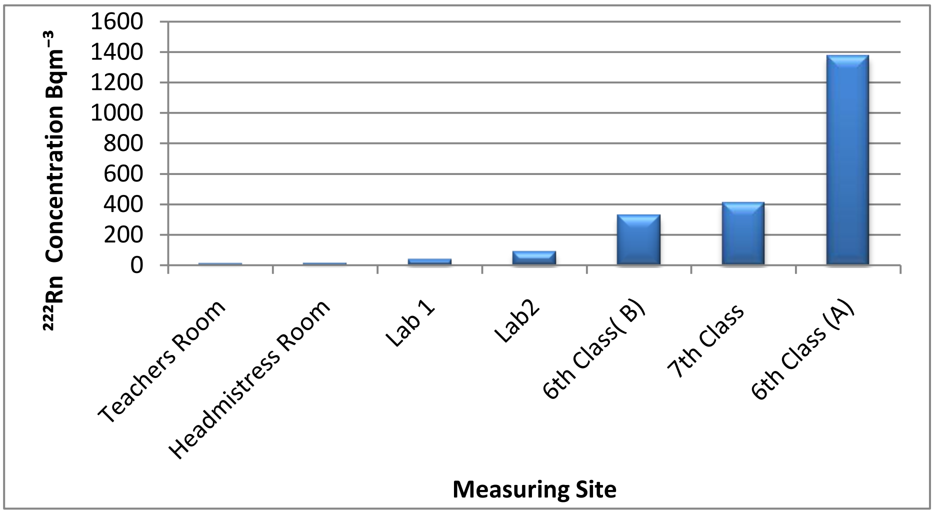

Figure 4. 10: Radon concentration in Bq/m^3 and measuring site in Al Sawahereh Girls School by RAd7.

high concentration of Radon was found in the air of the 6th class (A) that locates in the basement, followed by the 7th class, and 6th class (B).

In the three classes, Radon concentration was exceeded the recommended level. The measurements by using RAD7 followed with Cr-39 measurements in the same school.

4.4.6: Cr-39 Results in Al Swahereh Secondary Girls School

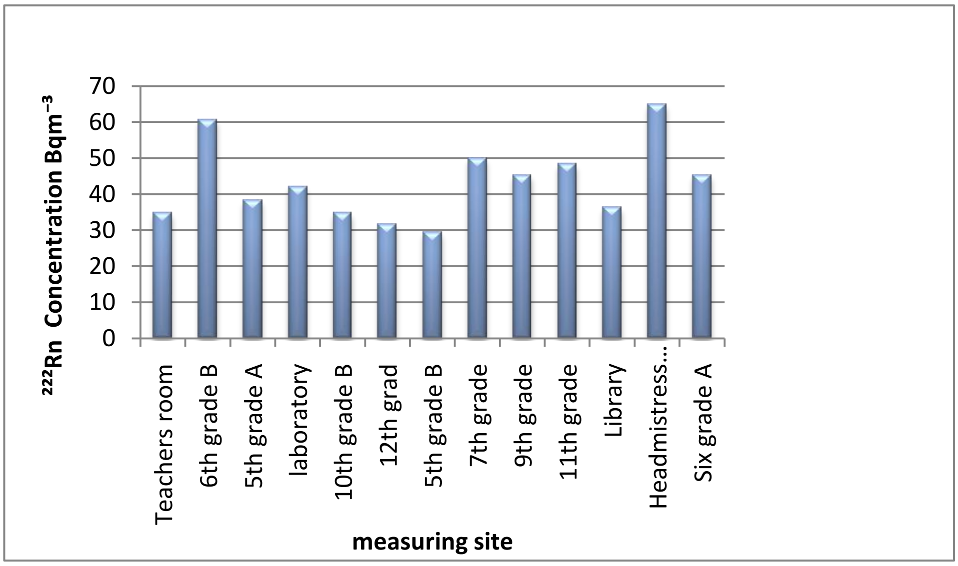

Figure 4. 11: Radon concentration in Bq/m^3 and measuring site in Al Sawahereh Girls School by Cr-39.

There is no measurements exceed the recommended levels the reason is the good ventilation of the rooms at measurements period, but RAD7 was measured through closed system in figure (4.10).

4.4.7:RAD7 Results in Al Swahereh Secondary Boys School

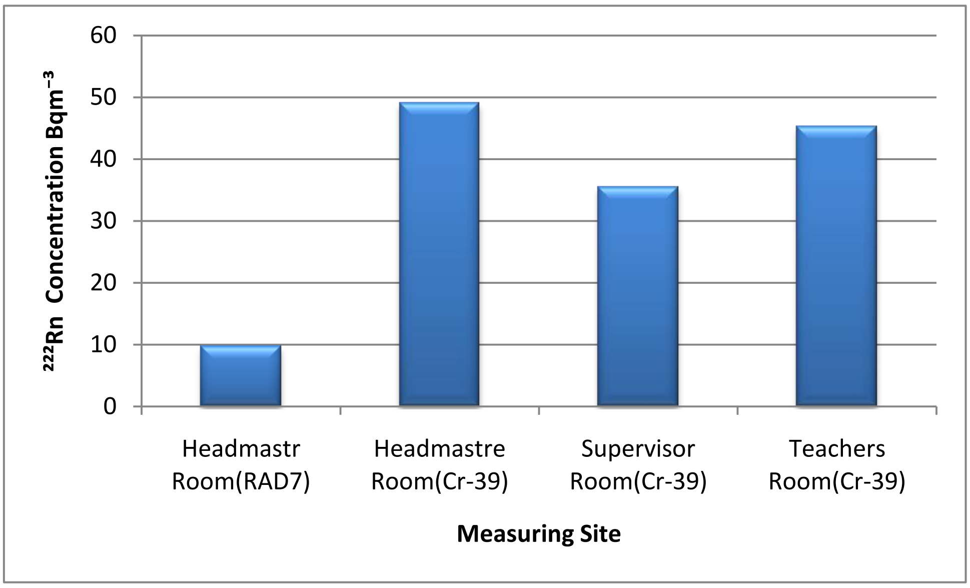

Figure 4.12: Radon concentration and measuring site in Al Sawahereh Secondary Boys School by RAD7.

All measurements in this school is low RAD7 and Cr-39 put in the same room headmaster room in different times and the levels did not exceed the recommended level. These measurements were taken between July and November months. The measurement by RAD7 was taken in summer time in Al Sawahereh school, table (3.2).

4.4.8:RAD7 Results in Al Masharee Primary Girls School.

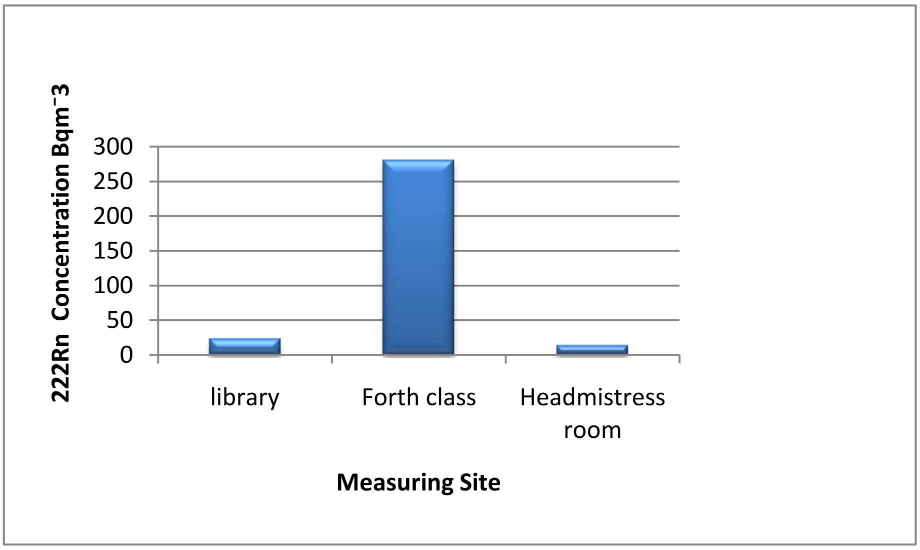

Figure 4.13: Radon concentration and measuring site in Al-Masharee' Primary Girls School by RAD7.

Forth class was measured high Radon level which exceeding the recommended level. The measurement was taken in January 2010 its cold month and the gas density is heavy this may cause the increased value.

4.4.9: Cr-39 Results in Al Masharee' Primary Girls School.

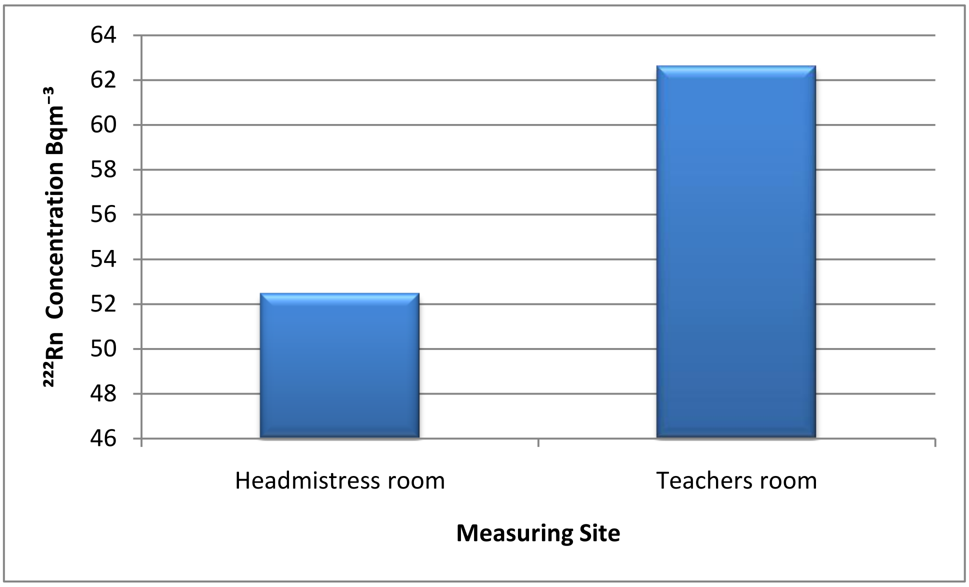

Figure 4. 14: Radon concentration and measuring site in Al Mashaaree' Primary Girls School by Cr-39.

RAD7 and Cr-39 were put in the same room headmistress room in different times and the levels in the two measurements do not exceed the recommended levels.

4.4.10:RAD7 Results in Al Masharee' Primary Boys School

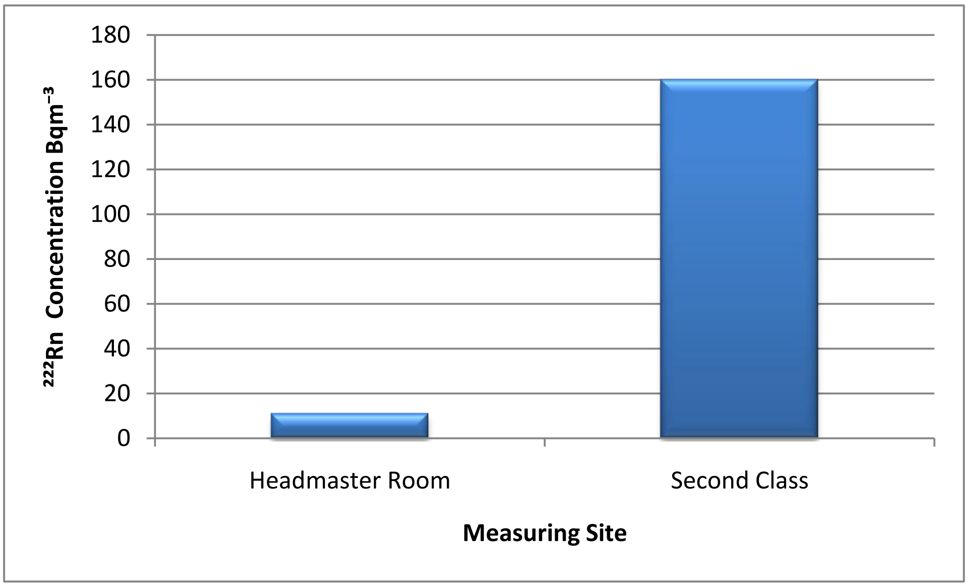

Figure 4. 15: Mean Radon concentration and measuring site in Al Masharee' Primary Boys School by RAD7.

Second class was measured high Radon level which exceeding the recommended level.

4.4.11: Cr-39 Results in Al Masharee Primary Boys School.

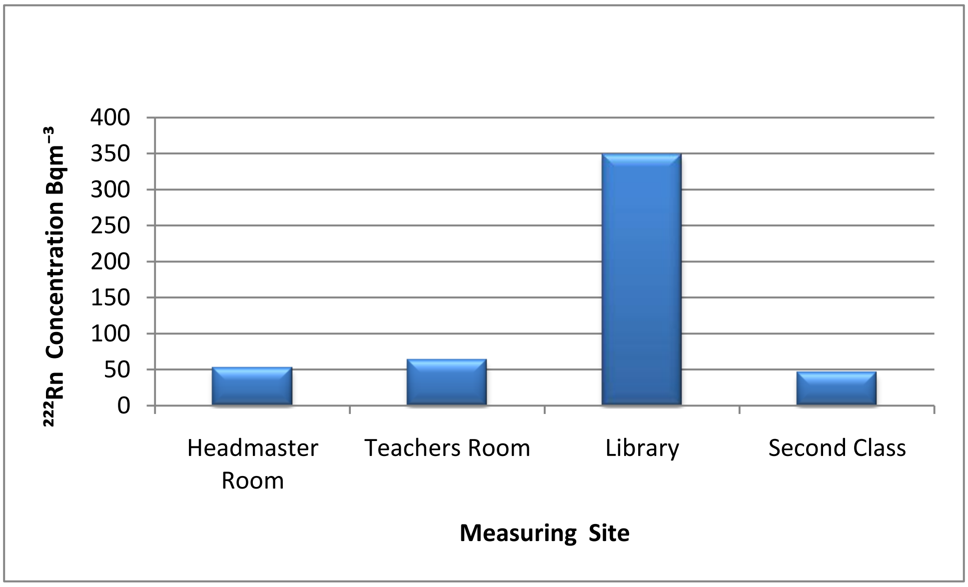

Figure 4. 16 Radon concentration and measuring site in Al Masharee' Primary Boys School by Cr-39 in different rooms.

The library was measured high Radon level which exceeded the recommended level. The room is closed most of the time, this make the level high.

RAD7 and Cr-39 were put in the same room headmistress room in different times and the levels in the two measurements do not exceed the recommended level. And the two device were put in the same room second classroom the two measurements differ from each other it's exceed the recommended level when RAD7 was used due to the cracks in the room and the measurement was taken in closed system, but it did not by using Cr-39 because the measurement was taken in normal ventilation at longest period of time.

4.4.12: Results in Maskat Secondary Boys School.

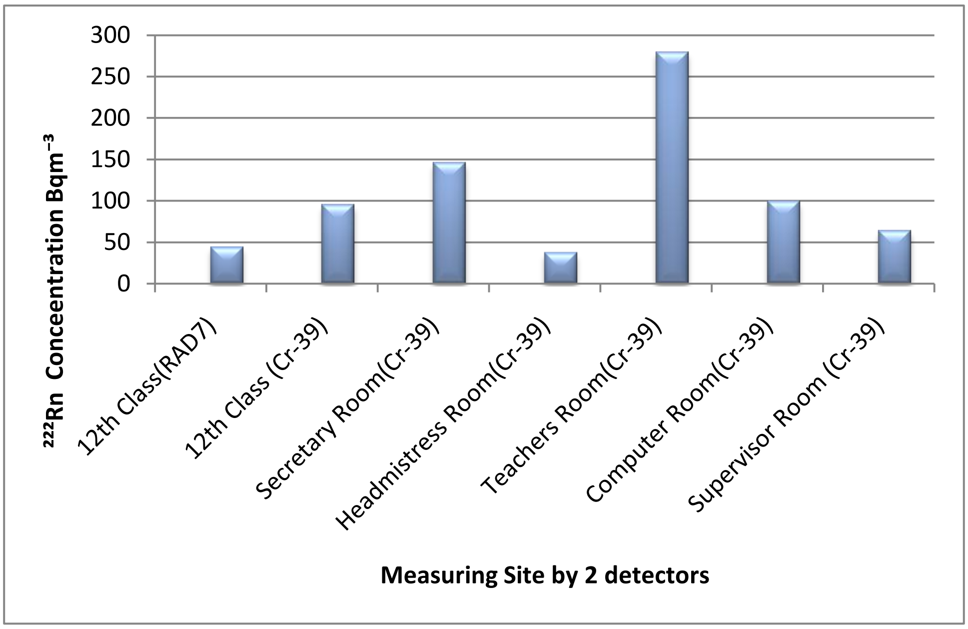

Figure 4.17: Radon concentration with measurement site in Maskat Secondary Boy's school.

In 12th class in Maskat school ^{222}Rn concentration was measured by two detectors RAD7 and Cr-39 at different times and the levels in the two measurements nearly similar to each other lower than recommended level but we can see that the secretary room and teachers room exceeded it, may be for poor ventilation, but the other rooms were not.

4.4.13: Results in Al Azaria Primary Girls School

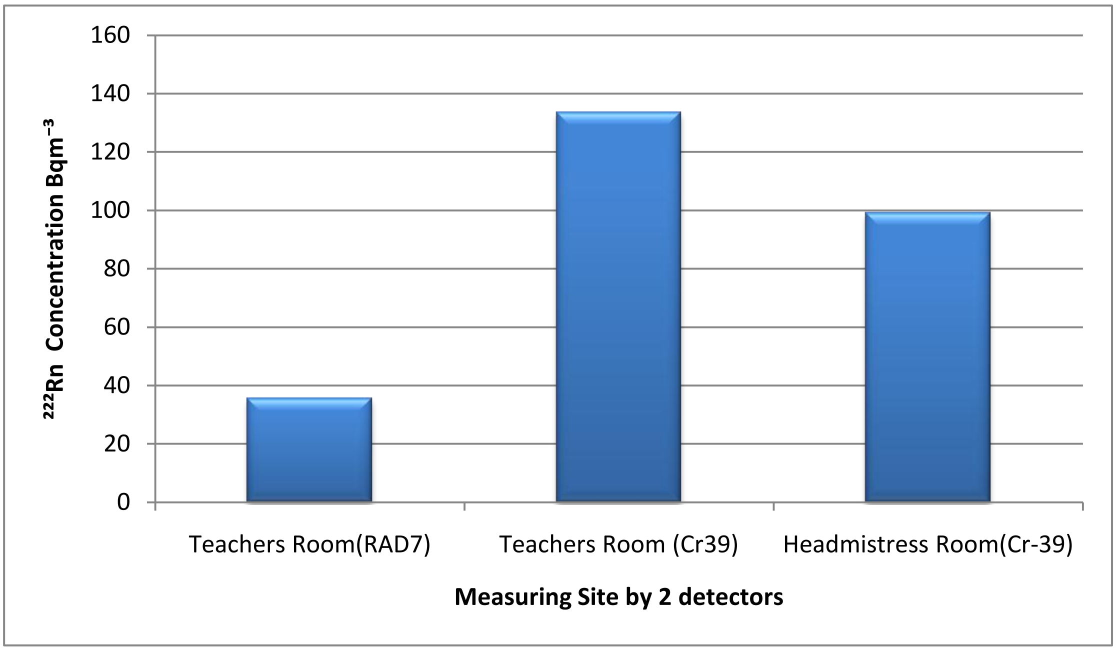

Figure 4.18: Radon concentration with measurements site in Al Azaria Primary Girls School by two detectors.

In teachers room ^{222}Rn concentration was measured by the two detectors RAD7 and Cr-39 in different times and the levels in the two measurements differ from each other but it reached the recommended level in headmistress and teachers rooms by Cr-39, this need retesting in the future.

4.4.14: Results in Al Azaria Secondary Girls School

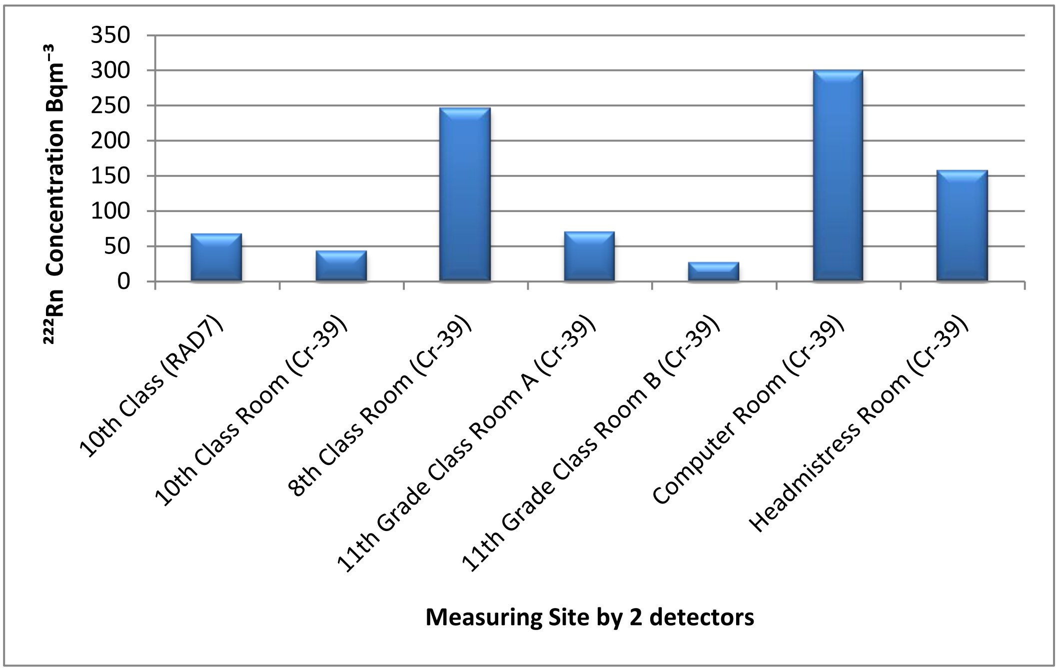

Figure 4. 19: Radon concentration and measuring site in Al Azaria Secondary Girls School by RAD7 and Cr-39.

In 10^{th} class ^{222}Rn concentration was measured in two detectors the levels are low, and did not exceed the recommended level. Three measurements were exceeded the recommended level, in 8^{th} class, computer room and headmistress room respectively but the other rooms' results were low. The levels are slightly high in some locations due to the poor ventilation, studying geology of the area with Radon concentration is important.

4.4.15: Results in Abu Dis Secondary Girls School.

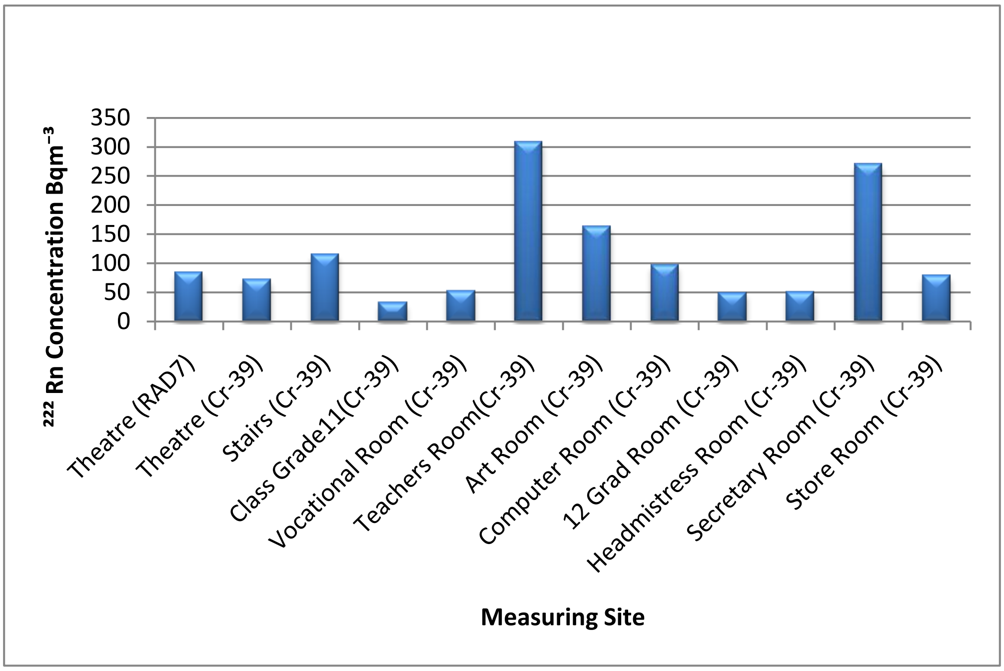

Figure 4.20: Radon concentration and measuring site in Abu Dis Secondary Girls School by RAD7 and Cr-39.

^{222}Rn concentration in the theatre was measured by two detectors RAD7 and Cr-39 in different times and the levels in the two measurements are low and not exceed the recommended level .Some measurements exceeded the levels at art room, store room, computer room, and stairs respectively, but other measurements value were low.

4.4.16: Results in Abu Dis Secondary Boys School.

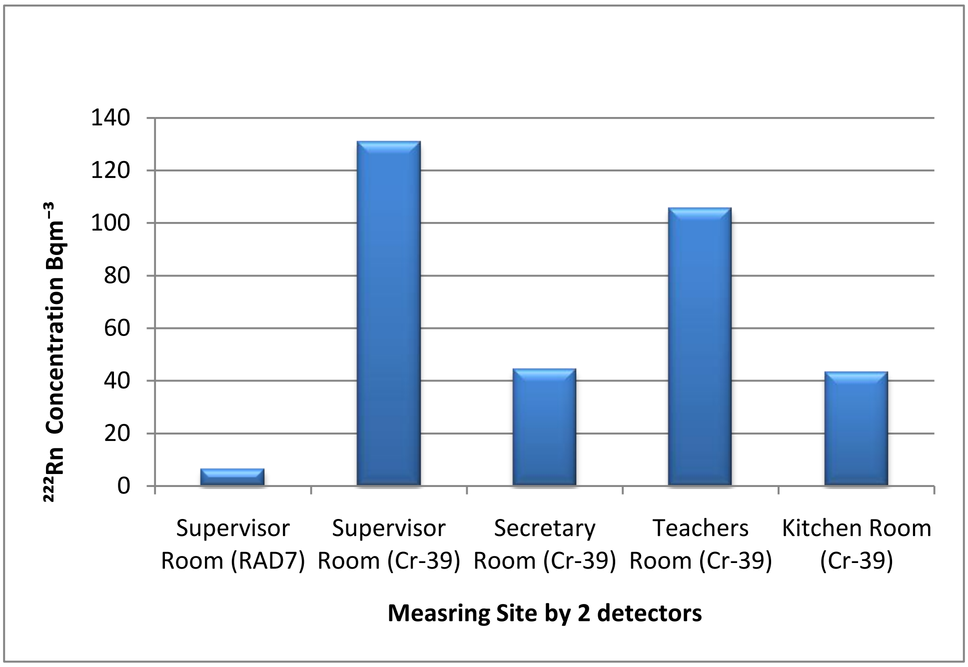

Figure 4.21: Radon concentration and measuring site in Abu Dis Secondary Boys School by RAD7 and Cr-39.

^{222}Rn concentration in supervisor room was detected by two devices RAD7 and Cr-39 in different times and the level which was measured by Cr-39 was exceeded the recommended level teachers rooms was exceeded it also, we notice that all measurement were taken in the second floor because of this reason the measurements were low see table (4.4.b).

4.4.17: Results in Abu Dis Primary Boys School.

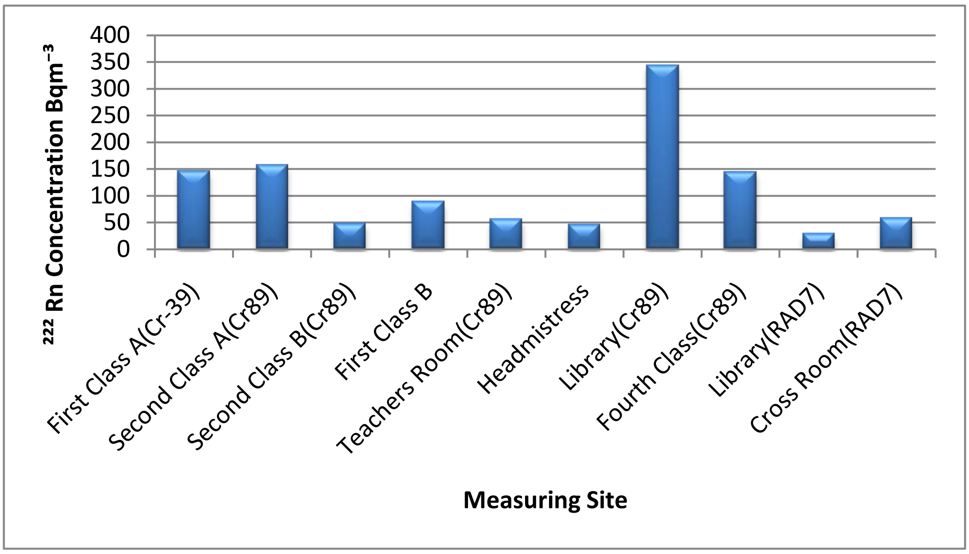

Figure 4.22: Radon concentration and measuring site in Abu Dis Primary Boys School by RAD7and Cr-39.

Three measurements were exceeded the recommended level. (The library, second class A,fourth class, and first class respectively , the other rooms had were low levels.

Library was measured in two detectors RAD7 and Cr-39 in different times and the level in the library by Cr-39 measurement is high and exceeding the threshold the room was closed all the time. The level is not high by RAD7 due to 48 hour measurement it is short time with comparison of Cr-39.

4.5: Results in Jericho and Hebron Using Solid State Nuclear Track Detectors.

4.5.1: Schools.

Cr-39 results of schools in Jericho and Hebron were presented the data in Tables (4.4) and (4.5) and Figure (4.24). (4 .25) and (4.26) were presented the diagrams of these data.

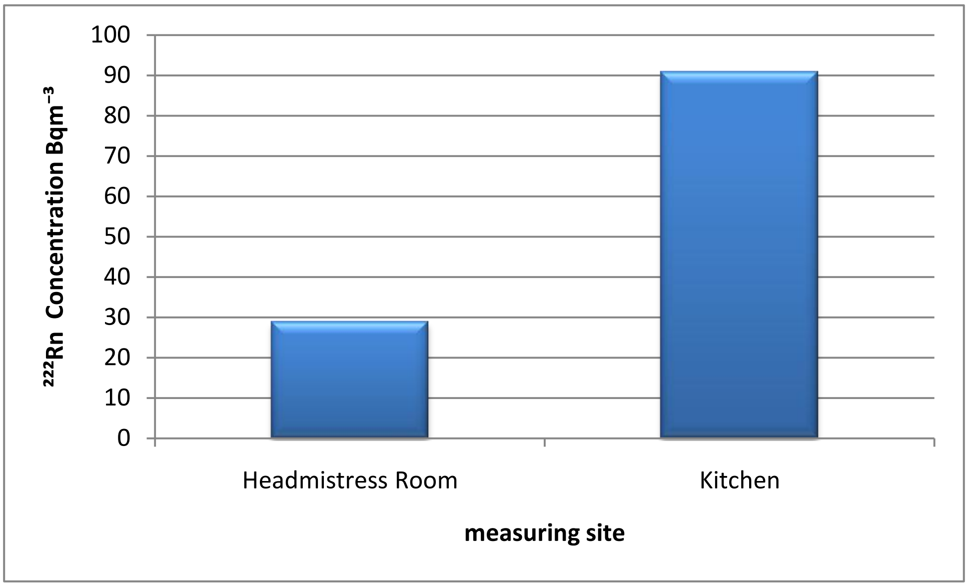

Figure 4.23: Radon concentration and measuring site in Aqubet Jaber Primary Girls School by Cr-39 in Jericho.

Three detectors were put in Aqubet Jaber camp in Aqubet Jaber school for girls only and one detector is lost Radon concentration in the two rooms were low and did not exceed the recommended level.

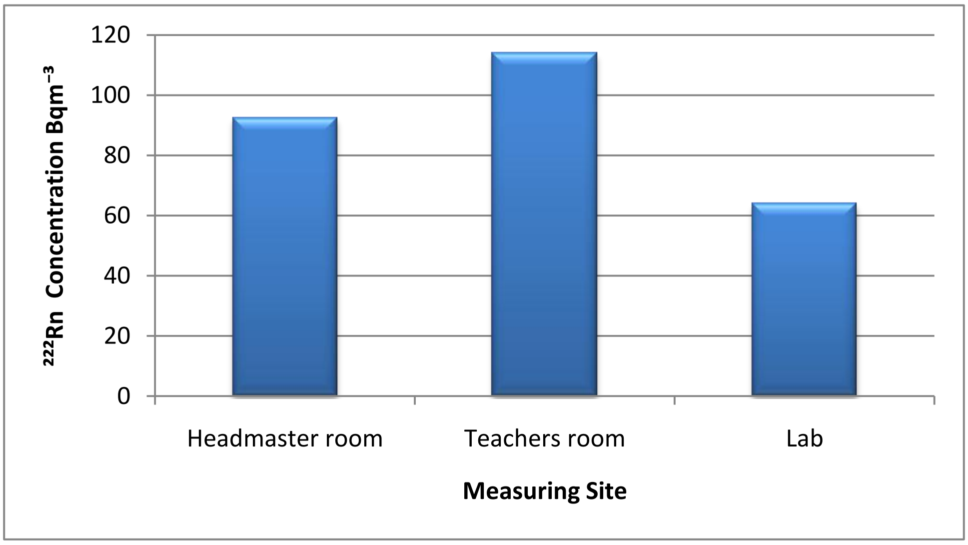

Figure 4.24: Radon concentration and measuring site in Salah Primary Boys School by Cr-39 in Hebron.

Teachers room was exceeded the recommended level in Salah School as WHO recommended.

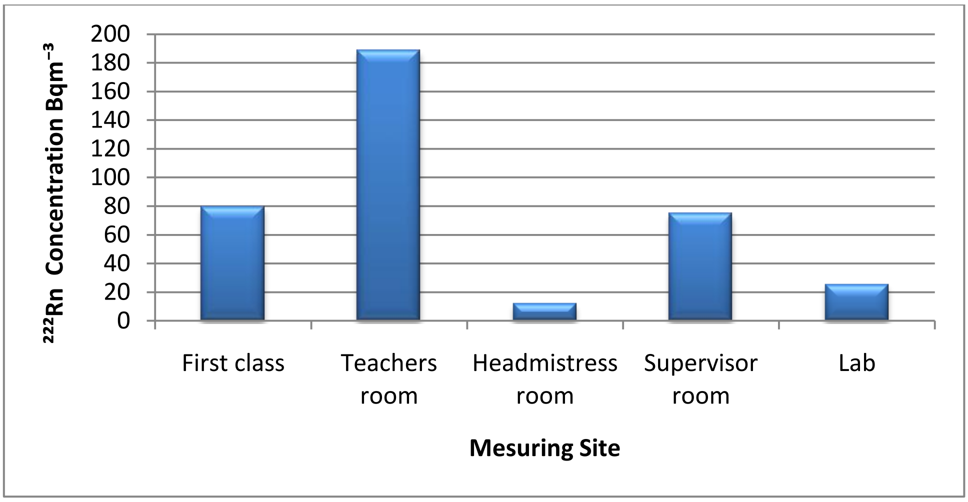

Figure 4. 25: Radon concentration and measuring site in Halhool Primary Girls School by Cr-39 in Hebron.

Teacher's room was exceeded the level it's on the ground; Radon enter from the soil.

4.5.2: Buildings.

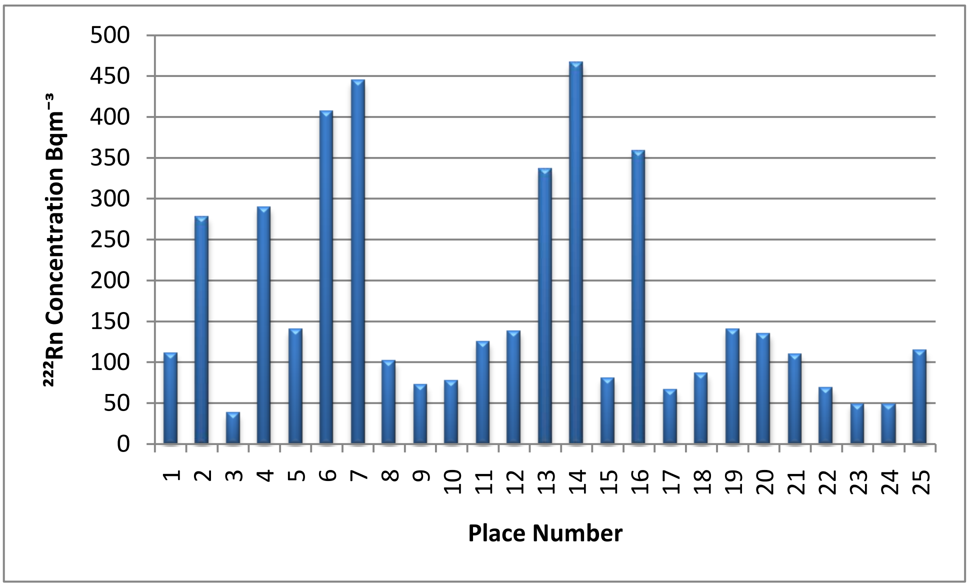

Figure 4.26: Radon concentration and measuring site in Jericho buildings by Cr-39.

There are several measurements exceeding the recommended levels in Jericho. When we take the mean of all these measurement it equal 171.05 Bq/m^3 this value was exceeded the recommended level also. This is due to the geology formation, the formation of the rock in these areas are Chert which has Uranium in its content.

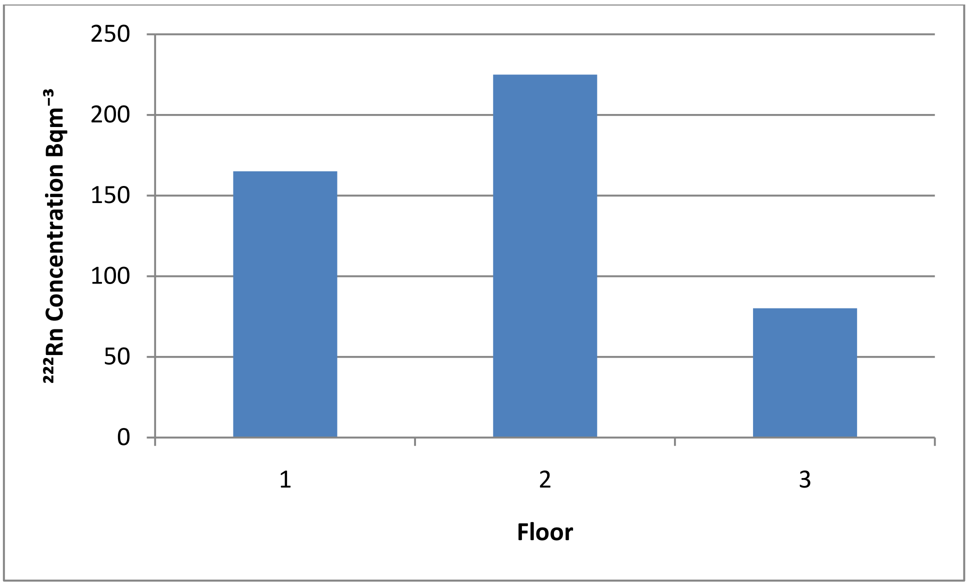

Figure 4.27: Mean Radon concentration and floor number in Jericho Buildings by Cr-39.

Most of high levels were in the first floor in spite of that when we took the average high values were found in the second floor as we saw in figure (4.27) this is may be for poor ventilation and bad sealing of the walls in the building or kind of material of construction.

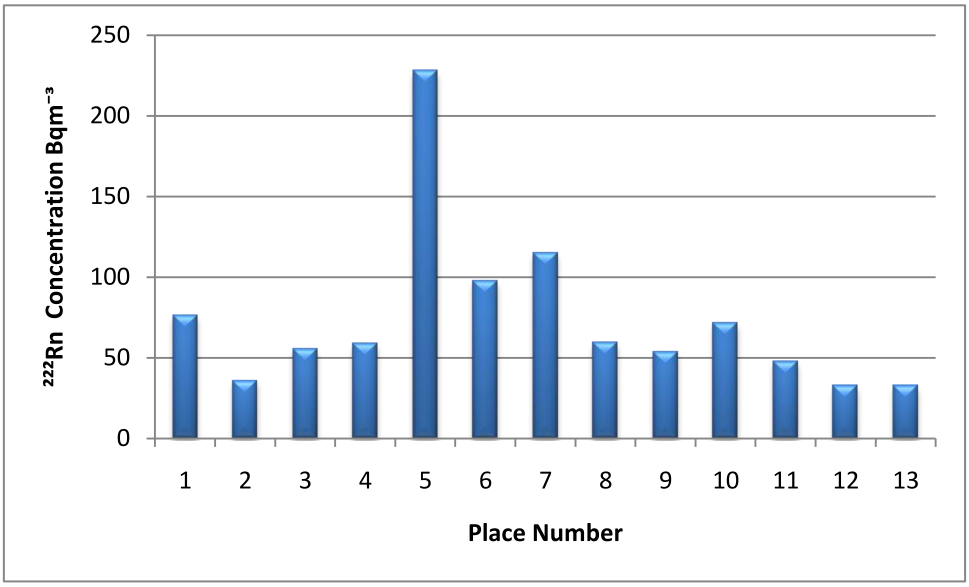

Figure 4.28: Mean Radon concentration and measuring site in Hebron buildings by Cr-39.

Two measurements were exceeded the recommended level in sleeping room and sitting room (No. 5and 7) this due to the poor ventilation.

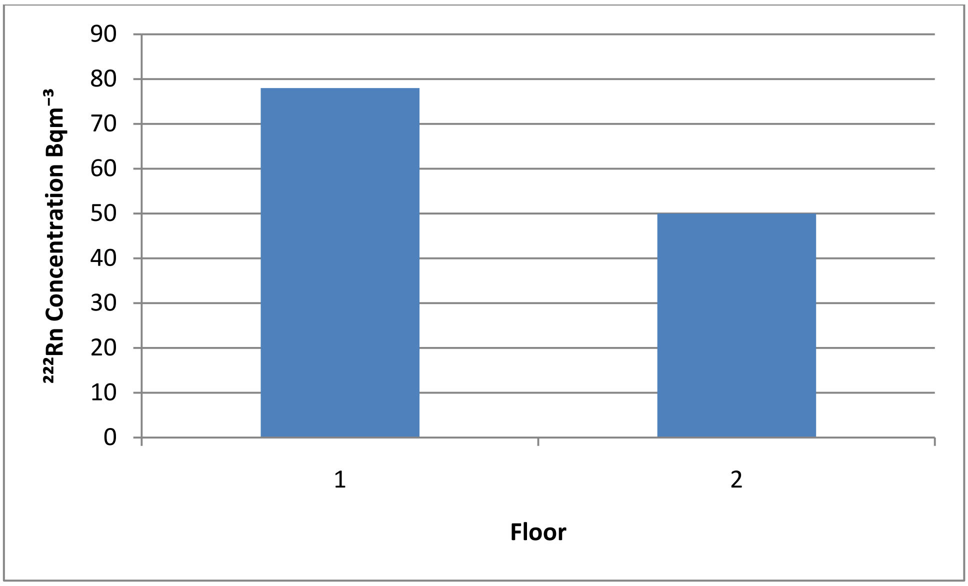

Figure 4.29: Mean Radon concentration and floor number in Hebron buildings by Cr-39.

Radon concentration in the first floor is higher than the second floor but it did not exceed the recommended level in Hebron area .

4.6.1: Indoor Radon concentration with the variable of time by RAD7

In the following charts Radon concentration with the measurement time 48 hours day and night for most of the measurements.

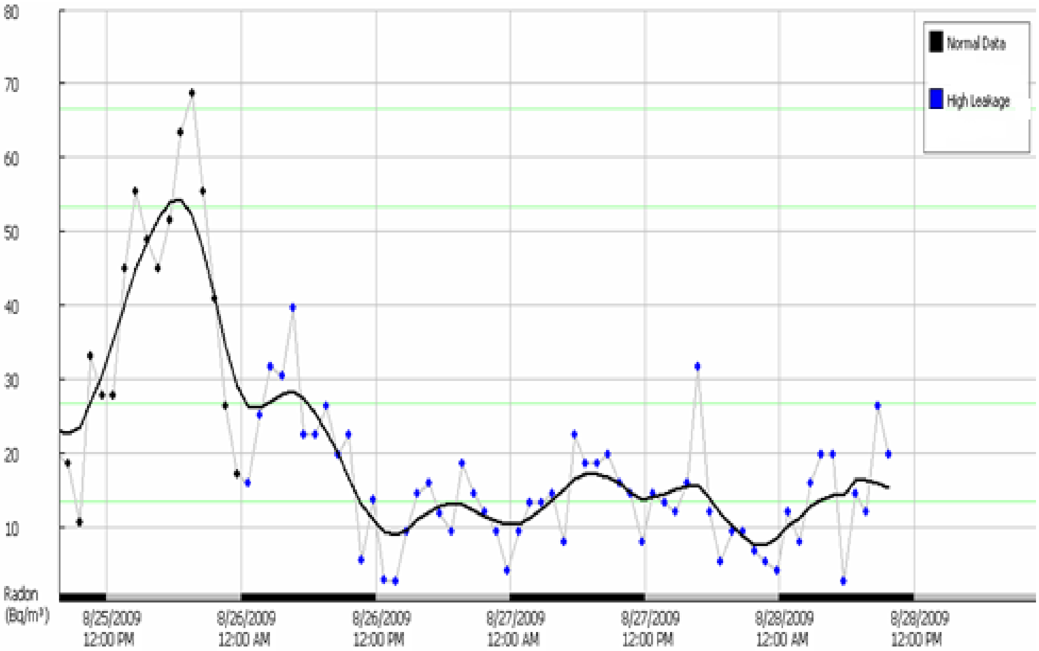

Figure 4.30: Radon concentration Bq/m3 with the time of the measurement (48 hours) In schools using RAD 7in Al Masharee' Primary School for Girls

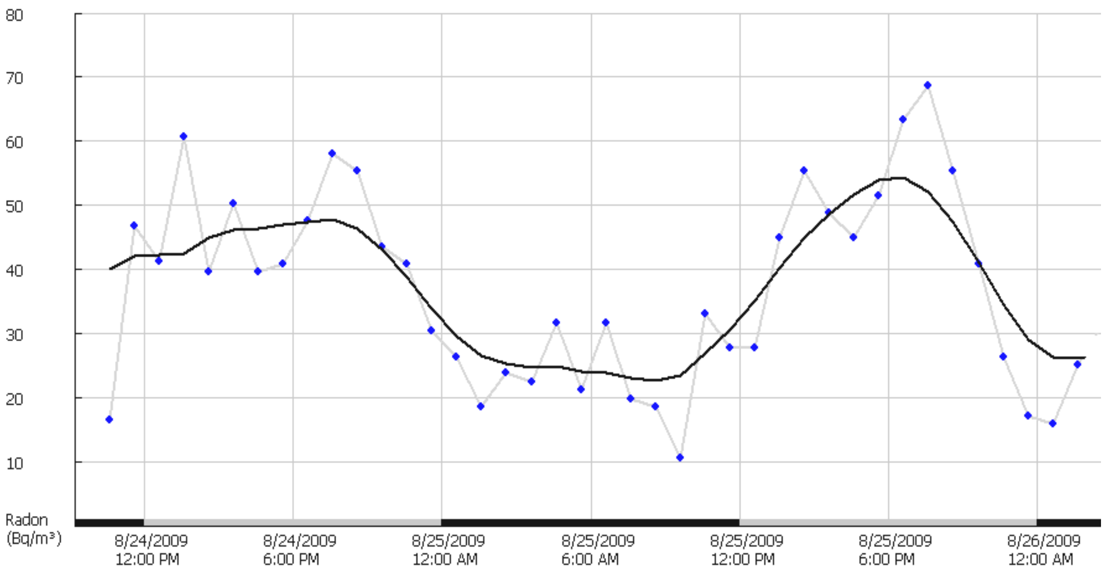

Figure 4.31: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7.in Al Azaria Primary School for Girls

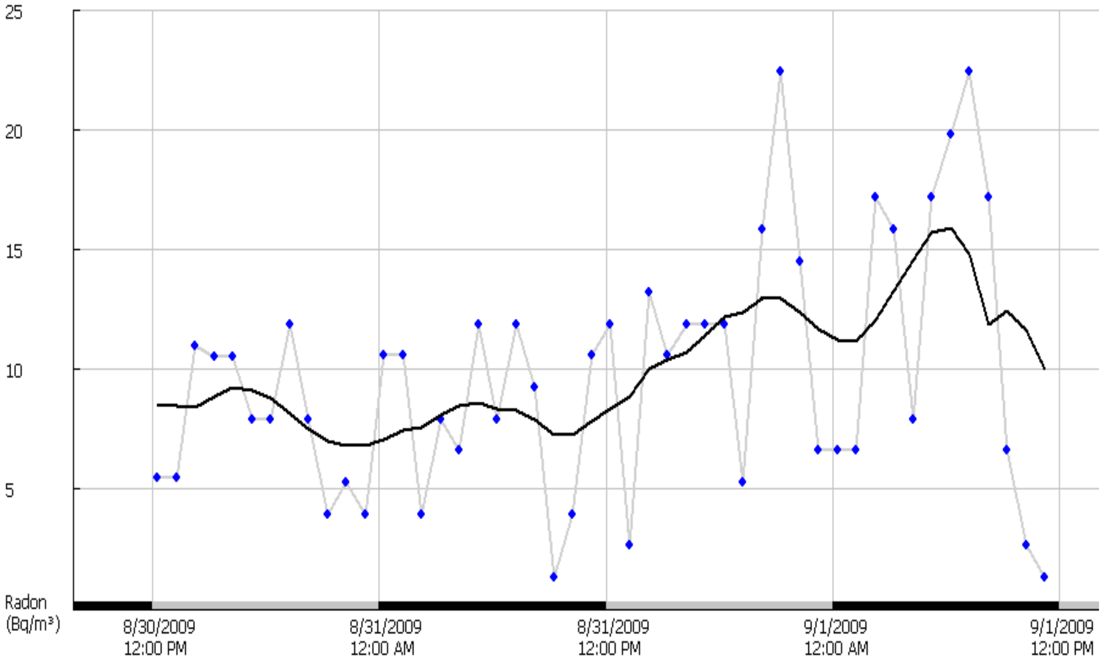

Figure 4.32: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7.in Al Swahreh Secondary School for Boys

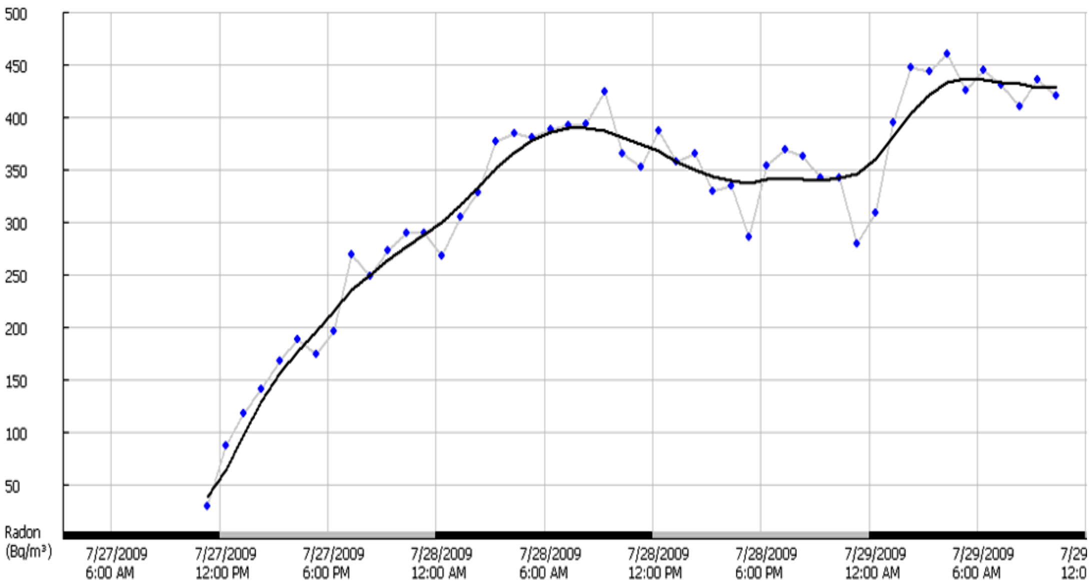

Figure 4.33: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7in Al Swahreh Secondary School for Girls

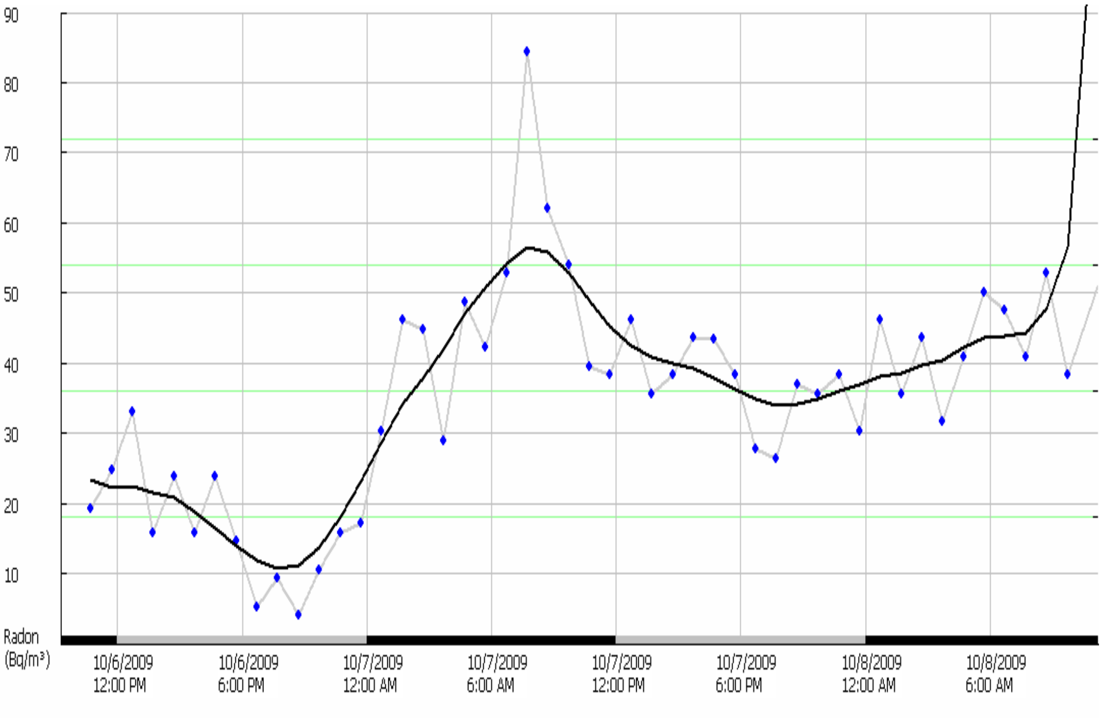

Figure 4.34: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7.in Al Swhreh Secondary School Girls

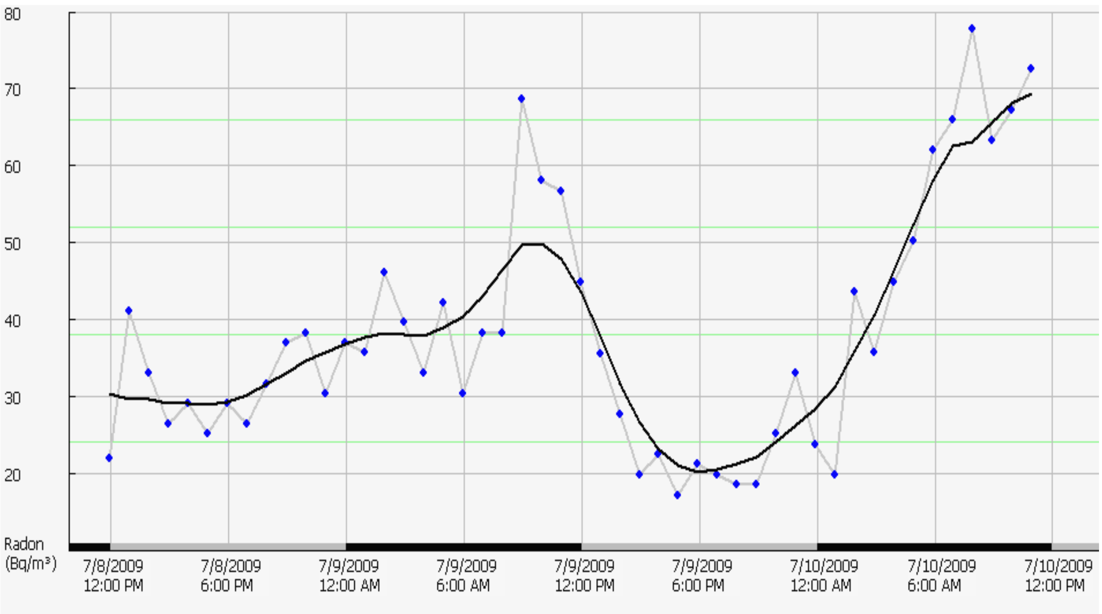

Figure 4.35: Radon concentration Bq/m3 with the time of the experiment (48 hours) In schools using RAD 7 in Yousef Al Khateeb Primary School for Boys

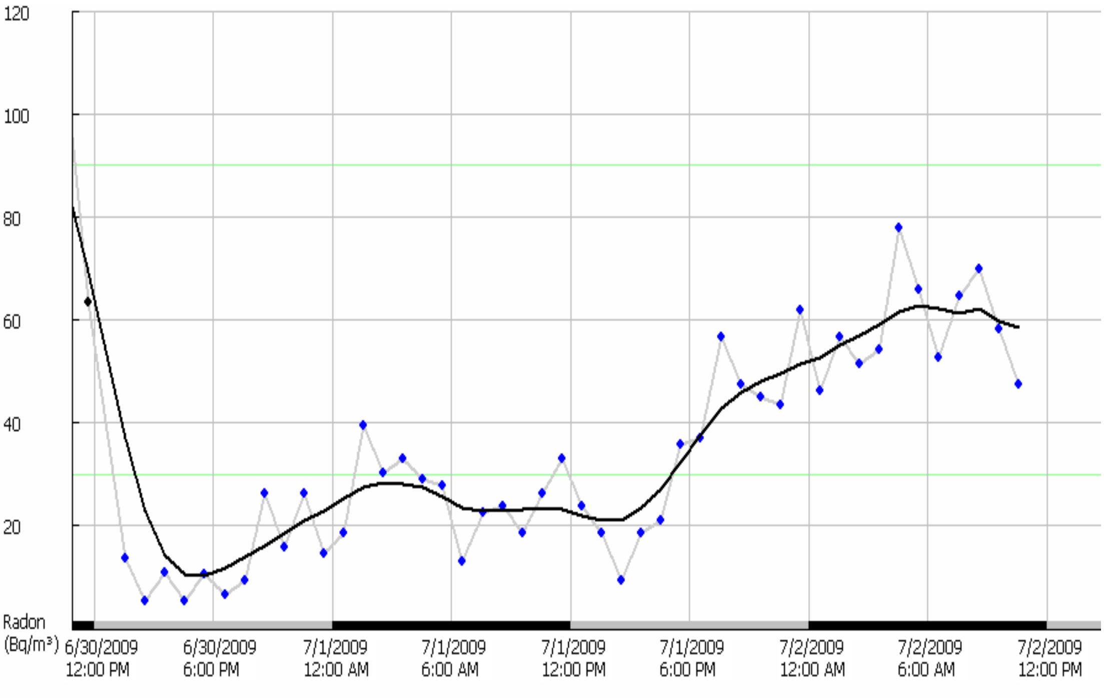

Figure 4.36: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7 Anata Primary School for Girls

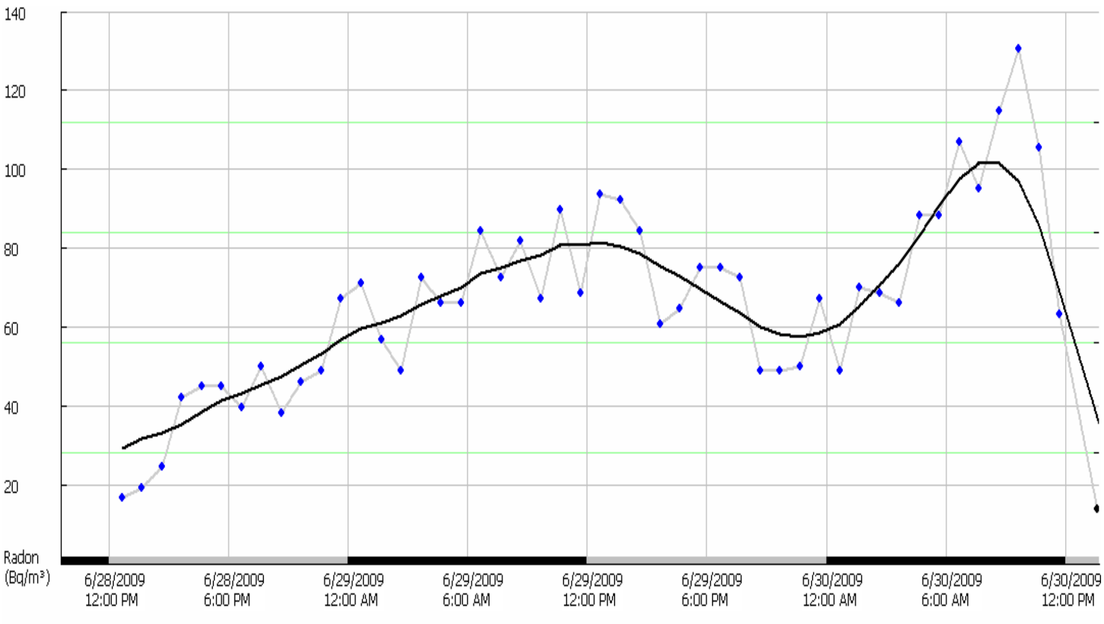

Figure 4. 37: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. Al Azaria Secondary School for Girls

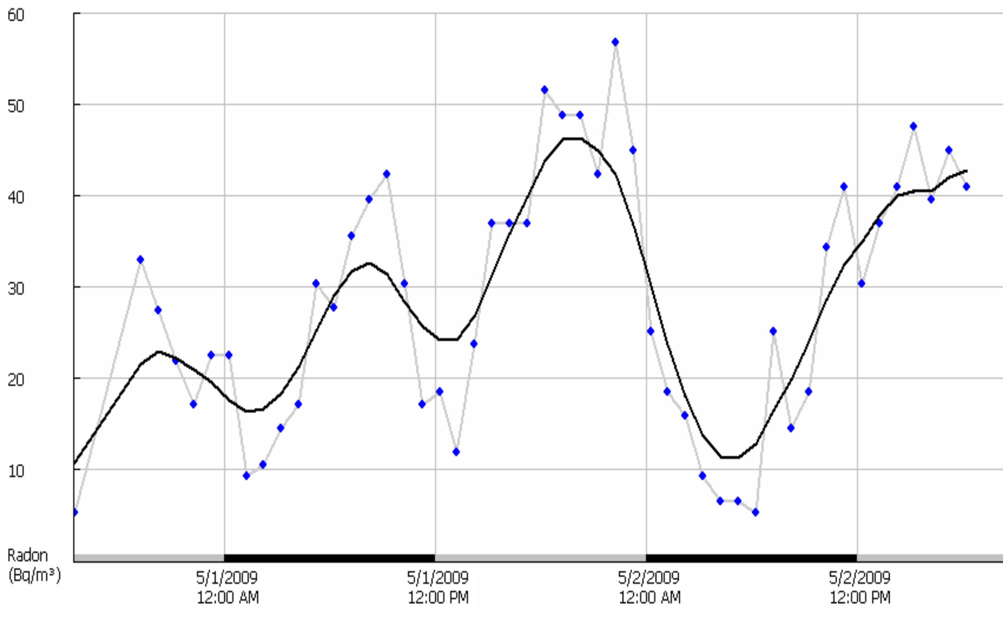

Figure4 .38: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7in. Abu Dis Primary School for Boys

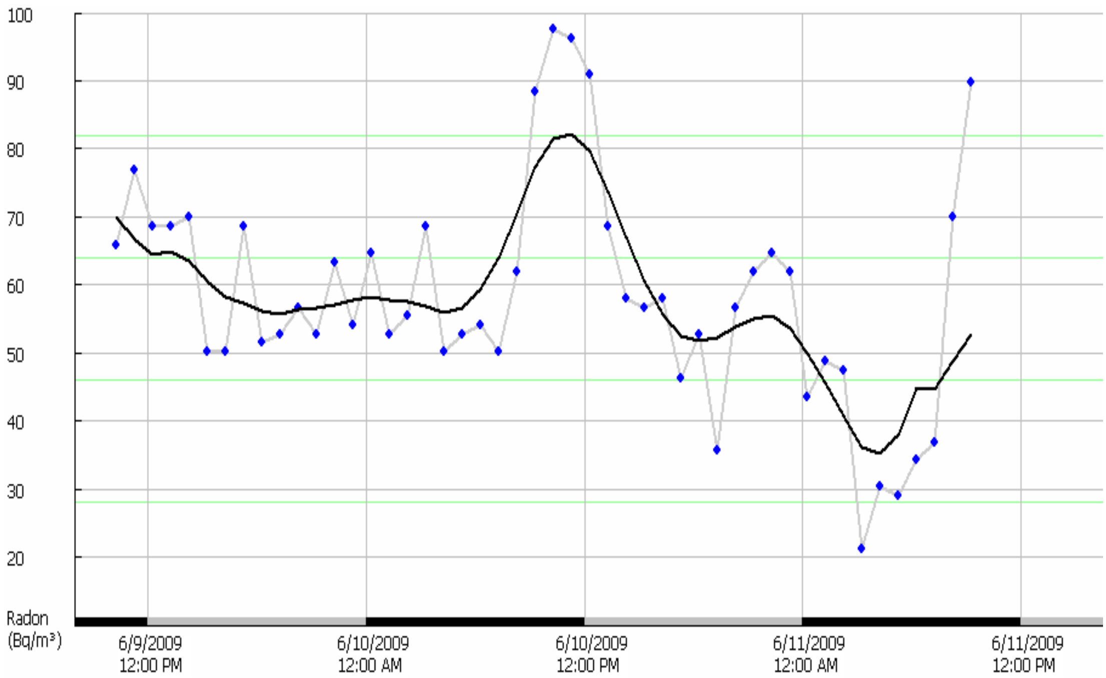

Figure 4.39: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7in Abu Dis Primary School for Boys

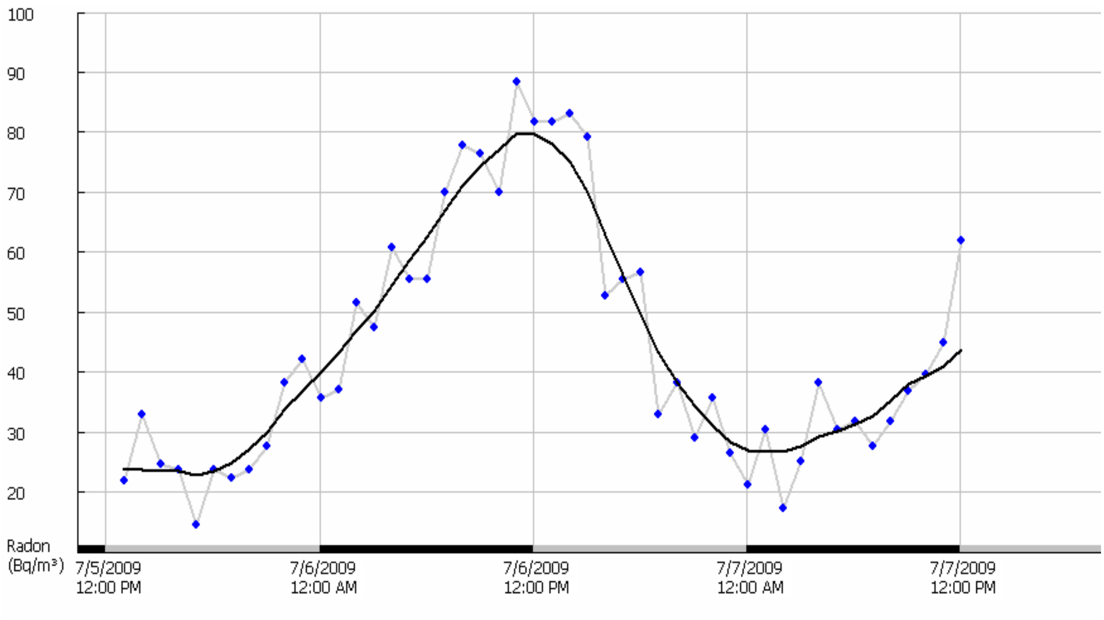

Figure 4.40: Radon mean concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7.in Maskat Secondary school for Boys

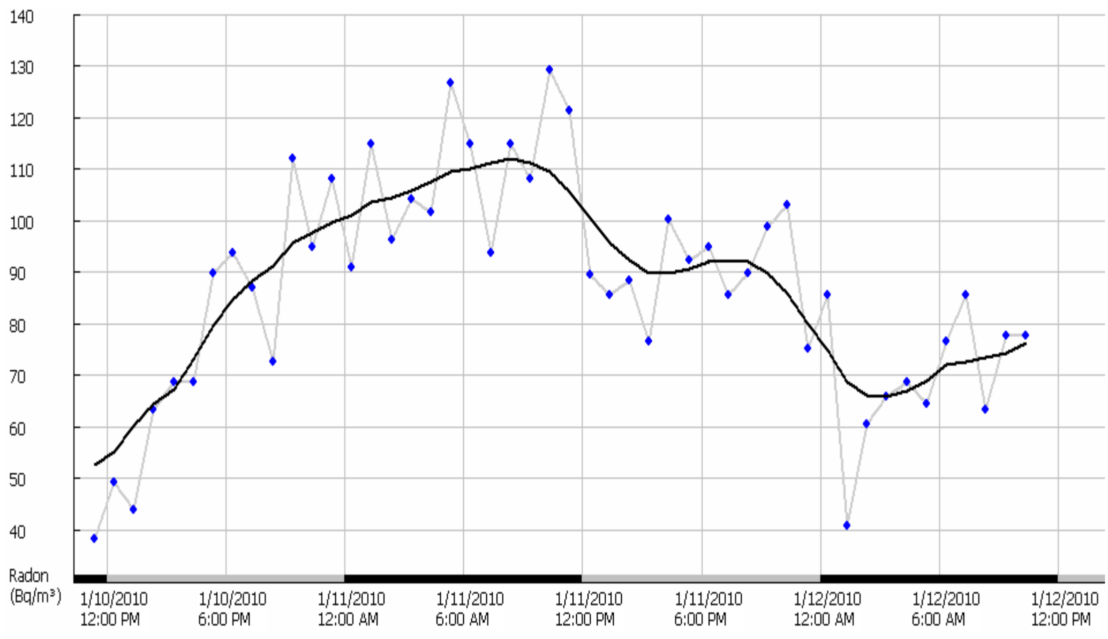

Figure 4.41: Radon means concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7.in Al Swahreh Secondary School for Girls

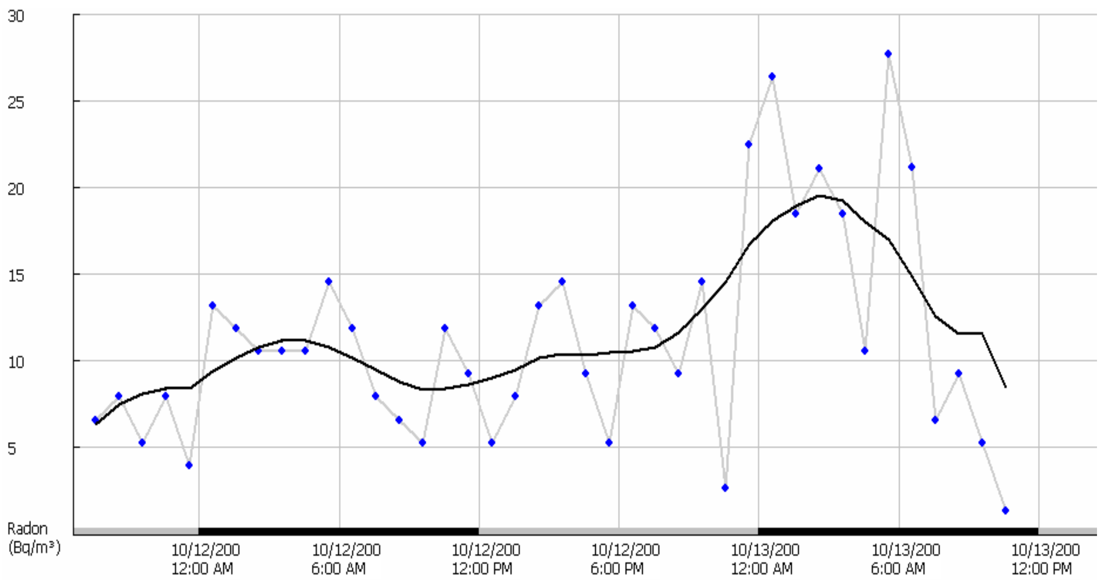

Figure.4.42: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. Al Swahreh Secondary School for Girls

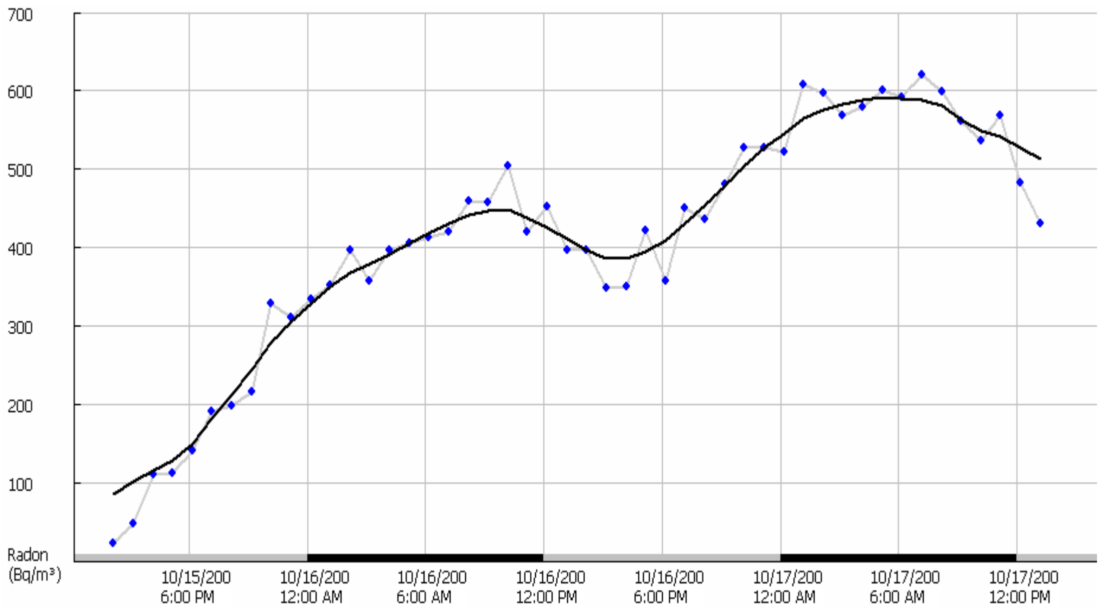

Figure 4.43: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. Al Swahreh Secondary School for Girls

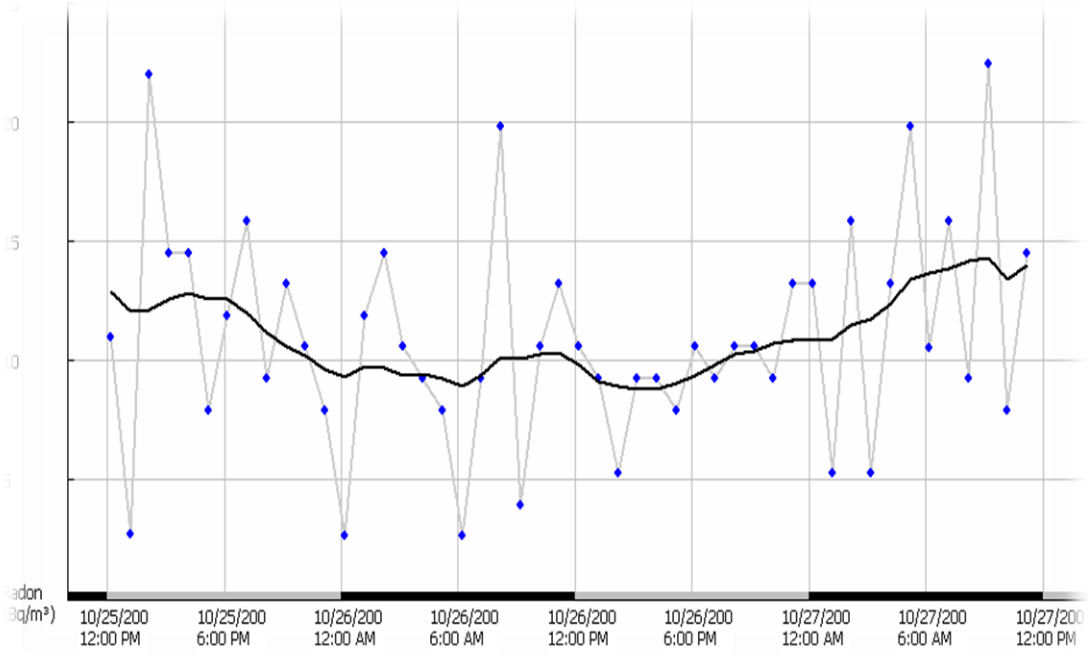

Figure 4.44: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. In Al Masharee' Primary School for Boys

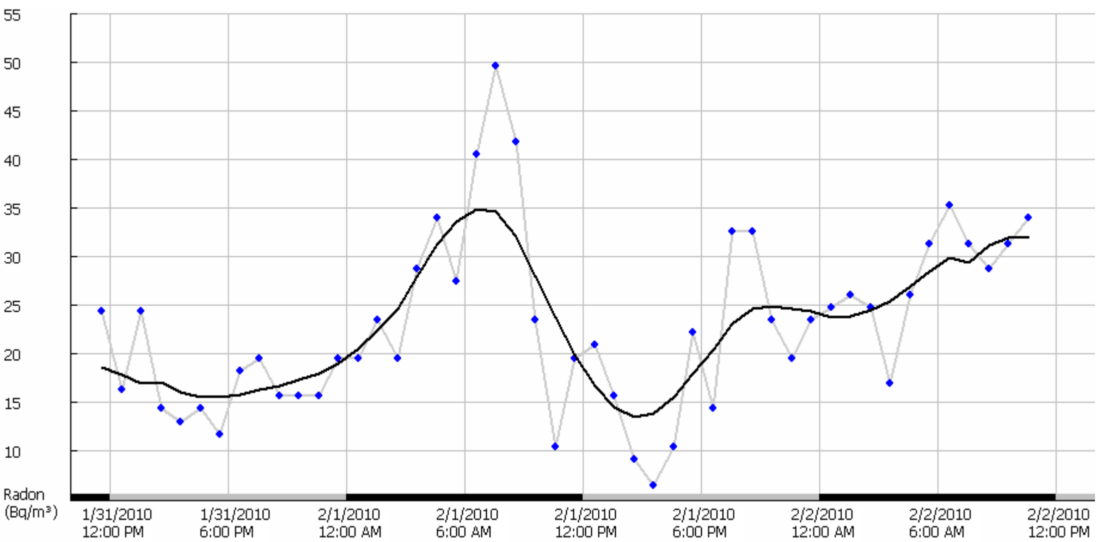

Figure 4.45: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. In Al Masharee' Primary School for Girls

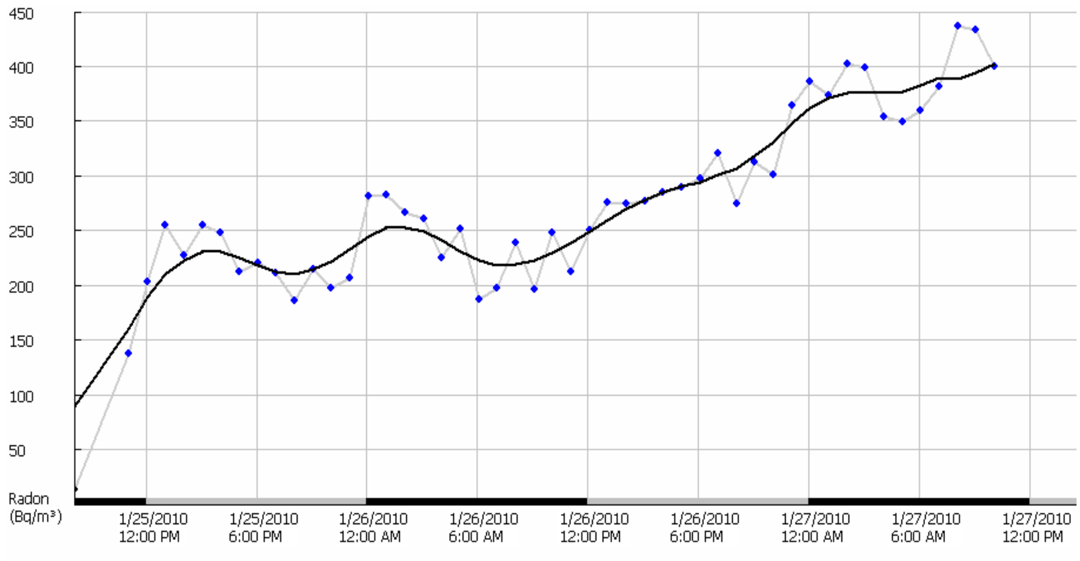

Figure 4.46: Radon concentration Bq/m3 with the time of the measurement (48 hours) in schools using RAD 7. In Al Masharee' Primary School for Girls.

Most of the figures above show that Radon concentration increase on day time and decrease on the night.

Chapter V

Conclusions and Recommendations

5. Introduction

As we expected in the hypothesis indoor Radon concentration was high in some places which were measured and the people in these places will exposure to high levels of Radon and may inhaled high dose which may cause lung cancer.

Type of materials of in old or new school is important in studying Radon concentration, but there is an influence between the floor level and Radon concentration.

Other important factor is the geology formation of the area where the measurements were taken if it has Uranium in the rock and soil which emanates Radon gas .so studying Radon concentration in the soil in the study area is very important.

5.1: Conclusions and Recommendations

5.1.1: Conclusions

RAD7 detector was used to detect Radon concentration in schools .It gives concentration every hour with the temperature, humidity and time day or night. Alpha track detectors named Cr-39 were used to measure Radon concentration also as most of investigations in the world due to its simplicity and accuracy.

RAD7 Radon detector was used to measure the ^{222}Rn concentration in some school rooms in Abu Dis, Al Sawahereh and Al Ezaria. The Rn values of Sawahereh show that high concentration was measured in some rooms. The high levels of Radon in the basement were related to flux of soil/rock air of the silica and chalk related to Wadi Al Quilt and Abu Dis formation respectively, these formation contains phosphate minerals, which have Uranium deposits (Shirva and Vulkan, 1997).

Radon levels varied from 1.3 to 1370 Bq/m^3 with effective dose 0.06 to 14.76 mSv/yr in schools, Radon levels varied from 11.94 to 348.81Bq/m^3 with effective dose 0.13 to 3.76mSv/yr in schools, and 20.36 to 465.94Bq/m^3 with effective dose 0.35 to 8.06 mSv/yr in dwellings by using Cr-39 detectors.

The results in Awawda, 2001 study in schools showed that the concentration of Radon in the area low and in acceptable level (20-40 Bq/m) this value is smaller than our study so other studies is recommended.

The results in Dabayneh, 2006 study in schools was in Tarqumia town in Hebron city in Palestine. The results showed that the annual effective dose equivalent in the schools was varied from 0.62 mSv/yr to 12 mSv/yr within an average of 1.76 mSv/yr. This value was slightly agreed with the dose of our study:

Results were showed that concentration was high in the basement and first floor this study agree with Al Sharif, 2001 study his results were showed that the concentration of Radon decreases with elevation.

Values decreased also from basement to first floor in Kosovo.in Bahtijari, et. al, 2007 study in schools

The correlation between concentration and humidity is positive when the concentration increases the humidity increases.

5.1.2: Recommendations:

Remedial action should be taken to reduce elevated Radon levels in the places where the concentration of Radon is high so we ought to:

Caulking Wall-Floor Joint, Sealing Joint between Slab and Foundation Wall to reduce the emission from the ground.

Fit the cracks in the walls and correct it. Radon-resistant by new construction before built the buildings by sealing and borders forbid Radon entering.

This study shows increasing the ventilation rate in schools and dwellings and completing Radon survey in Palestine.

New investigation between the Radon concentration and the geology of the place was needed especially where Radon concentration results are high.

Studying Radon concentration in the soil and rock in the study area is strongly recommended.

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تقييم تركيز غاز الرادون في المساكن في شرقي القدس والخليل واريحا

ملخص

الرادون عنصر مشع في سلسلة عنصر اليورانيوم 238 وهي احدى سلاسل النشاط الاشعاعي والتي تحصل في الطبيعة نجده في تركيزات مختلفة في التراكيب الجيولوجية هذا الغاز المشع ينطلق من الارض الى الجو ثم ينتشر بشكل كبيرليتمكن من الدخول في المساكن مثل البيوت والمدارس والبنايات الاخرى من خلال الشقوق والفراغات بين الجدران .

اهمية هذا الغاز تكمن من خلال اثاره الخطرة على الصحة والتي تقود الى سرطان الرئة حيث اعتبر هذا الغاز المسبب الثاني لمرض سرطان الرئة بعد التدخين ،هذا التاثير الضار للغاز يمكن تقليله من خلال دراسة غاز الرادون وتحديد تركيزه وتحديد الجرعة الممتصة التي يتعرض لها السكان ومن ثم اتباع سبل التخفيف اللازمة من انبثاق غاز الرادون للحد منه.

في هذه الدراسة استخدم جهاز كاشف الرادون (RAD7) وكاشفات الرادون الصلبة (Cr-39) لقياس تركيز غاز الرادون في مدارس مناطق مختلفة من القدس مثل العيزرية وابوديس والسواحرة في الفترة ما بين ;كانون ثاني2009-شباط 2010 كما قيست نسبة غاز الرادون في بعض المدارس والبيوت في منطقتي الخليل واريحا.

تراوح معدل مستويات غاز الرادون في المدارس التي استخدم فيها كاشف الرادون المستمر ما بين 1.3- 1370 Bq/m^3مع جرعة ممتصة تتراوح بين 0.06- 14.76 mSv/yr وترواحت مستويات غاز الرادون في المدارس التي استخدم فيها كاشفات الرادون الصلبة بين 348.81-11.94 Bq/m^3
مع جرعة ممتصة 3.6-0.13 mSv/yr وتراوحت بين 465.94-20.36 Bqm^{-3}في المساكن التي استخدم فيها نفس الكاشف.

اظهرت النتائج ان نسبة غاز الرادون تقل مع الارتفاع ولم تكن هناك علاقة واضحة بين عمر البناية ونسبة الغاز. في بعض المدارس كانت نسبة الغاز عالية وكذلك سجلت نسب عالية للغاز في مساكن مختلفة في اريحا وجرعة عالية ممتصة تعدت الحد الموصى به والتي قد تشكل خطورة على ساكنيها لذلك يوصى بزيادة التهوية واخذ سبل التخفيف اللازمة.

ان نسبة غاز الرادون العالية في المنطقة الشرقية للقدس يعود الى مجموعة صخور جبل المكبر المسيطرة على المنطقة ويعتقد ان منطقة وادي القلط الغنية بصخور الفوسفات هي مصدرهذا الغاز.

وكذلك ان نسبة التركيز العالية التي وجدت في اريحا حيث تكوين السمرا الذي يتشكل من الرمل والطمي يخزن غاز الرادون لفترة طويلة والتي تسبب تراكم هذا الغاز في المنطقة مما يسبب وجوده على طول الصدع.