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

تقييم تركيز غاز الرادون-222 في هواء منازل مدينة رفح جنوب
قطاع غزة-فلسطين.

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إقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

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

تقييم تركيز غاز الرادون-222 في هواء منازل مدينة رفح جنوب قطاع غزة- فلسطين.

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ اياد ابراهيم هايل بلاونة لنيل درجة الماجستير في كلية العلوم قسم الفيزياء وموضوعها:

تقييم مستويات تركيز غاز الرادون -222 في هواء منازل مدينة رفح جنوب قطاع غزة-فلسطين
Indoor radon-222 concentration levels evaluation in Rafah in southern part of Gaza strip , Palestine

وبعد المناقشة العلنية التي تمت اليوم الإثنين 23 محرم 1438هـ، الموافق 2016/10/24 الساعة الواحدة ظهراً في قاعة مؤتمرات مبنى القدس ، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في كلية العلوم/ قسم الفيزياء.

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله والتوفيق ،،،

نائب الرئيس لشئون البحث العلمي والدراسات العليا

أ.د. عبدالرؤف علي المناعمة

Abstract

Indoor radon has been recognized as one of the health hazards for mankind because long-term exposure to radon increases the risk of developing lung cancer.

In this study, we report on the radon concentration levels, in the houses of Rafah city during summer season of the year 2016 using the CR-39 track detectors. Passive diffusion Radon dosimeters containing CR-39 solid state nuclear track detectors of good quality were used to measure Radon and its daughter's concentrations throughout Rafah city. Our sampling strategy was to distribute the dosimeters in houses in Rafah city (Tal El Soltan , Balad(Rafah camp) and El Genena) at different geographic parts of the region. These dosimeters were distributed in bedrooms, living rooms and kitchens. The (150) detectors were left for three months during the period from June to August of 2016. The collected detectors were chemically etched by using NaOH of (6M) concentration at temperature 70°C for a period of 5 hours. Each detector was counted visually using an optical microscope with power of (40*10). Tracks in the three distinct regions of Rafah city were observed, through the area (1cm^2) of the detector. The average Radon concentration at all the regions was found to be 73.8 Bq/m^3 (1.99 pCi/l) with a range of values between 16.5 and 150.4 Bq/m^3 (0.44 and 4.06 pCi/l), and average standard deviation of 15.1 Bq/m^3 . The average indoor radon concentration obtained was below the indoor radon concentration action level (148 Bq/m^3) recommended by Environmental Protection Agency (EPA). The results obtained in this work are quite limited and should only be considered as indicative of the variability in radon concentration that expected in normal building in Rafah. However, in spite of this limitation, certainly this study provides an extrapolations about radiation concentration in general form in Rafah city, and indicates the health effects that radiation might cause in future, from environmental point of view.

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

الملخص

يعتبر غاز الرادون في المنازل أحد الأخطار التي تهدد البشرية في حالة التعرض لفترات طويلة لهذا الغاز لأنه يزيد من احتمالية الإصابة بسرطان الرئة.

لقد تم في هذه الأطروحة قياس تركيز غاز الرادون- 222 في هواء منازل مدينة رفح جنوب قطاع غزة، وذلك باستخدام كاشف الحالة الصلبة (مجراع الرادون السلبي) للمسارات النووية والمعروف تجاريا باسم CR-39. تم توزيع 150 مجرعا في ثلاث مناطق متباينة في مدينة رفح لتشمل معظم مناطق المدينة الجغرافية وهي تل السلطان، البلد (مخيم رفح)، حي الجنينة والمشروع .

بعد مرور تسعين يوما جمعت المجراعات وعولجت كيميائيا باستخدام محلول هيدروكسيد الصوديوم المخفف بالماء المقطر بتركيز (6) مول وعند درجة حرارة 70 درجة مئوية ولمدة 5 ساعات تقريبا ثم عدت المسارات المتولدة في الكواشف والموجودة في وحدة المساحة (1mm^2) من خلال مجهر ضوئي قوته (10*40) عبر 4 مناطق واضحة علي الكاشف.

وجد أن تركيز الرادون في أماكن الدراسة يتراوح بين 16.5 Bq/m^3 و 150.4 Bq/m^3 وتبين أن القيمة المتوسطة لتركيز الرادون في مدينة رفح 73.8 Bq/m^3 مع متوسط انحراف معياري يساوي 15.1 Bq/m^3 ووجد أن تركيز الرادون في المواقع كالتالي:

تل السلطان 75.6 Bq/m^3 ، البلد (مخيم رفح) 73.2 Bq/m^3 ، الجنينة 72.6 Bq/m^3

المتوسط العام لتركيز الرادون يعتبر أقل من الحد الأعلى التي أوصت به وكالة حماية البيئة (EPA) ويساوي 148 Bq/m^3

رغم أن النتائج التي تم الحصول عليها محدودة نوعا ما، إلا أنها تشير إلى تغير تركيز غاز الرادون في منازل مدينة رفح، وبالتأكيد فان مثل هذه الدراسة تزودنا بمعرفة تركيز الإشعاع بشكل عام في مدينة رفح، والأخطار الصحية الناجمة عنها و يمدنا بمعلومات مستقبلية عن الإشعاع لها فائدة كبيرة من الناحية البيئية.
الكلمات المفتاحية: كوشف الCR39، مستويات تركيز الرادون 222، الجرعات، التعرض.

Dedication

To my dear wife,

my friend Yasser,

son Yousef,

and my daughters Mai, Lama and Jana.

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It gives me pleasure to express my thanks to all those who have assisted me in the preparation of this study. My sincere gratitude goes to my supervisor, Dr. Samir S. Yassin, for useful discussions, kind help and guidance throughout this work.

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Chapter1

Introduction

Chapter 1

Introduction

1.1 Background

Gaza Strip is a narrow piece of land lying on the coast of the Mediterranean Sea at roughly 31° N latitude and 34° E longitude, about 32 km north of the Egyptian border. The coast has sand dunes of about 20 to 40 m in height above sea level. Gaza Strip is a very crowded place with an area of 360 km². Its weather is mild in winter and dry and warm to hot in summer. Remedial measures will be presented in view of the results that could be helpful to the environmental point of view part of this work. In fact, remarkable increases of many diseases are spreading in the country, and these include acute and chronic respiratory disease as well as lung and blood cancer. This has been reported in a 2000 report of the Ministry of Health (Awad and Abu Arqoub, 2002).

Therefore, a radioactive pollution monitoring system should be established in Gaza to avoid more possible radioactive risks since chronic dose from natural sources has been increasing concern worldwide.

Radon problems have been identified in almost every state of the world. In most of the developed countries of the world, the radon problems have been taken seriously. Radon reference and action levels have been set (Khan, 2005), (Khattak, 2015).

1.2 Radiation

Radiation is the amount of energy released as particles or electromagnetic waves that come from radioactive elements. These elements will attempt to reach stability by emitting radiation. The radiation travels through space or matter and they divide into two types: ionizing radiation and non-ionizing radiation.

1.2.1 Ionizing radiation

The radiation concerning pollution is ionizing, radiation of sufficiently enough energy to ionize atoms and molecules. It is capable of stripping electrons from atoms and breaking chemical bonds, creating highly reactive ions (atoms or molecules that have an electric charge). Radioactive materials, that contain atoms that have unstable nuclei, occur naturally and emit ionizing radiation in a process known as radioactive decay. The most common types of ionizing radiation are alpha particles (α), beta particles (β), gamma rays (γ), and X-rays.

I) Alpha particles

Particles consist of two protons and two neutrons bound together to form nucleus of helium atom. It has a positive charge +2 and carries kinetic energy always in the range of (4 to 8)MeV. Alpha particles do not penetrate far into material and can be stopped easily. Alpha particles have harmful effects within a human tissue when they absorbed rather than an external hazard.

II) Beta radiation (particles)

Beta particles are electrons emitted from nucleus of radioactive atom and have a negative charge. It carries kinetic energy always from(0 to 2)MeV they can travel in high speed one meter in air but not in straight line and they can penetrate human skin. Beta particles can produce skin injury .Beta particles will be harmful when deposited internally. However, beta particle with very low energy can be stopped by aluminum foil or thin wood.

III) Neutrons particles

Neutrons are natural particles that are normally contained in the nucleus of all atoms and may be removed by many processes like collision and fission. The neutron has no electrical charge and have large mass and can be absorbed or scattered by a nucleus of an atom or interact with it. It has the potential to penetrate matter deeper than any other charged particles.

IV) Gamma radiation

Gamma rays are photons packets of pure energy usually between 50 and 2000 KeV. and they are emitted from nucleus of an atom when it excites. They are not electrically charged particles and mass less. Gamma rays usually have higher energies than X-rays and both can penetrate matter further than any particles. They can travel from 1 to hundreds of meters in air and can easily go right through a human tissue and they may be called "penetrating radiation" thus they cause hazard to human. They can early detected by Sodium Iodide detector, for example of some atoms emitting Gamma rays such as; Technisume 99 (^{99}Tc), Iodine 131 (^{131}I) and Cesium 137 (^{137}Cs).

V) X-rays

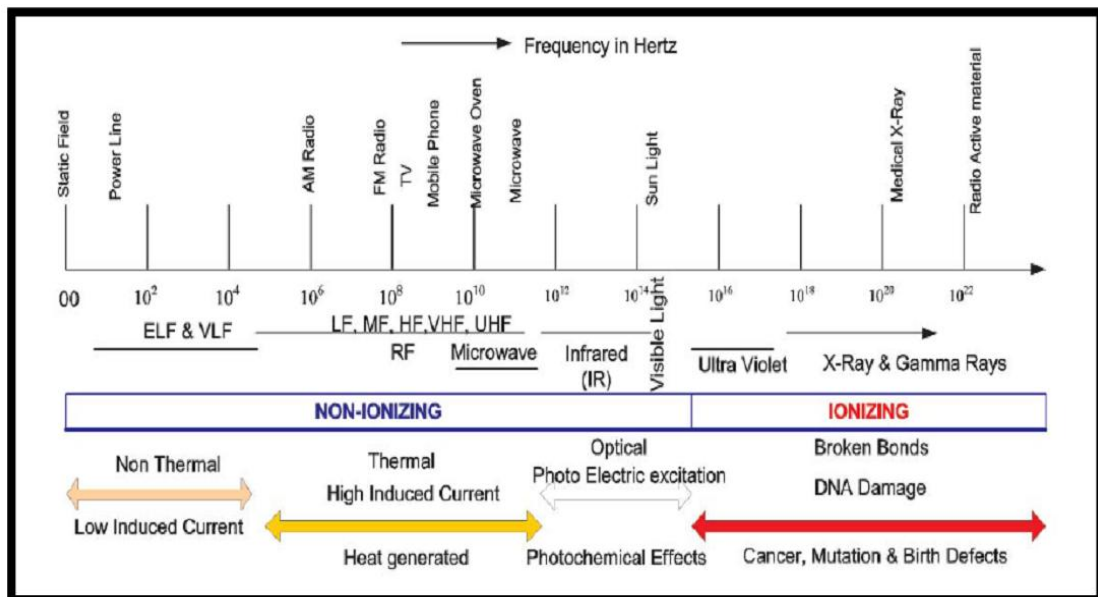
X-rays are electromagnetic radiation or photons that can be emitted by machines or decay of radionuclide.

X-rays are able to travel many feet's in air and many inches in human tissue. They can

penetrate most materials and called "penetrating radiation" and make external hazard on human. The dense material is used for shielding from x-ray and Gamma -ray .

1.2.2 Non ionizing radiation

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight. Non ionizing radiation ranges from extremely low frequency radiation, as micro wave. Extremely low frequency radiation in the range of 100 Hz or less, see figure (1.1).Because it is lower energy radiation, the use of this type of radiation in medical fields and everyday life has fewer health risks than ionizing radiation in forms such as x-ray. (EPA,1988,pp. 32-36) .



Figure(1.1): Electromagnetic spectrum (Musleh, 2015).

1.3 Radiation sources

There are different types of radiation; some are more energetic than others. Radiation is produced naturally when unstable elements try to stabilize themselves and give off excess energy in the process.

We can divide radiation sources into two categories **natural sources and man- made sources**. Natural background radiations that are found naturally in air, water and soil. They are even found in us, being that we are products of our environment. Every day, we ingest and inhale radionuclides in our air, food, and the water. Natural radioactivity is common in the rocks and soil that make up our planet, in water and oceans, and in

our building materials and homes. There is nowhere on Earth that you cannot find Natural radioactivity.

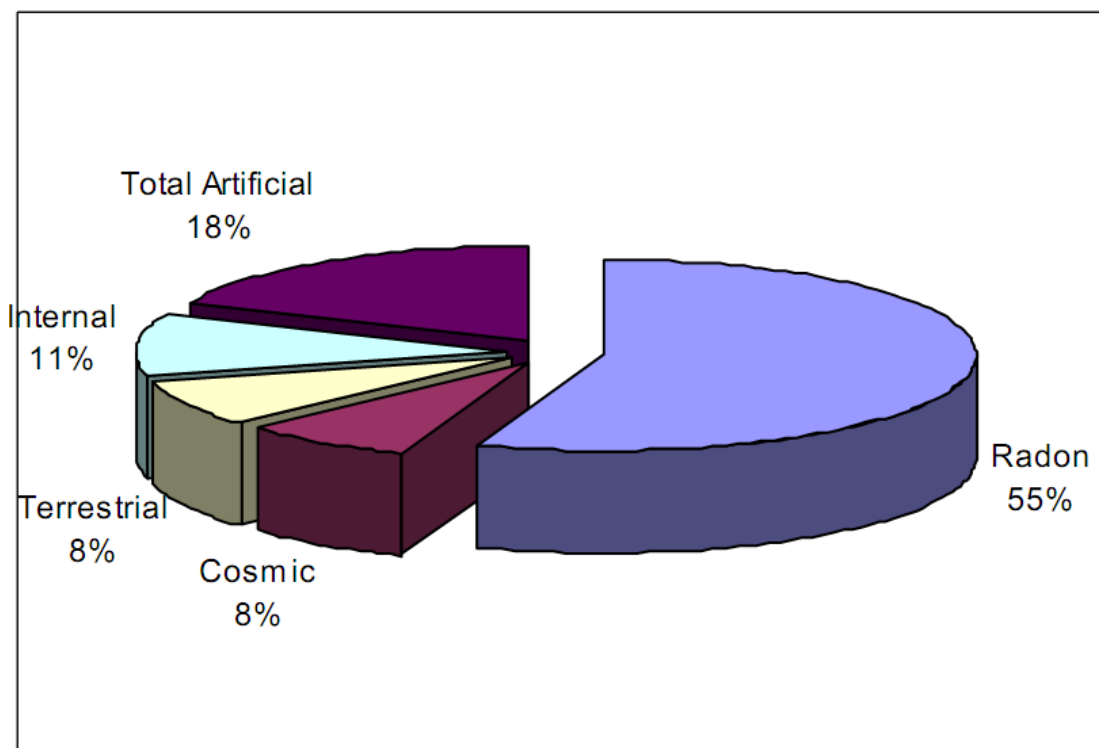


Figure (1.2): Annual effective dose equivalent (UNSCAR,1986).

1.3.1 Natural sources

D) Cosmic radiation

The cosmic radiation is produced from our solar system (interstellar space and sun). It composed to very wide range from high speed heavy particles to high energy photons and mesons. When radiation comes from space and sun, it penetrates atmosphere and interact with it then produce radioactive nuclides as Carbon-14 (^{14}C), Tritium(^3H) and Beryllium-7 (^7Be).

The dose from cosmic radiation varies in different parts of the world due to differences in elevation and the effects of the Earth's magnetic field (Abu Saleh, 2005).

Cosmic radiation is classified as primary and secondary type, primary radiation have high energy particle and mostly large particles, and comes from the sun and outer space.

Little of this type reaches to earth surface and other radiation interact with atmosphere. When it interacts with atmosphere, it produces the secondary type of cosmic radiation with lower energy in the form of photons, electrons and neutrons, which arrive to earth surface. Therefore we can say that atmosphere is a shield, so that the rate at sea- level is less than at high altitudes. Magnetic field is the other factor affects reaching radiations to earth also, the rate of radiation on pole to the equator decreases about 10% (Durrani and Ilic,1997).

II) Radiation from terrestrial

When the universe is created, the radionuclides were found in it. Earth has some radionuclide in rocks, soil, ocean water, air and vegetation. It is in small quantities. Terrestrial radiation varies depending on some factors such as half lives of the radionuclides and the type of the rock. These radionuclides are decreasing in its activity because it's decreasing to half value after certain time, the radiation varies from sandstone limestone and granite.

III) Internal radiation

Internal radiation comes from radioactive materials that occur naturally in the human body. Potassium and Carbon are the primary sources of internal radiation exposures. In addition to the cosmic and terrestrial sources, all people have radioactive potassium – 40, carbon – 14, lead – 210, and other isotopes inside their bodies from birth. The variation in dose from one person to another is not as great as the variation in dose from cosmic and terrestrial sources (Abu Saleh, 2005).

VI) Radon

is a radioactive gas, first discovered in the early 1900s. During the early studies of radioactive elements, it was found that “emanations” themselves radioactive were associated with many of newly identified radioactive elements. The gas associated with uranium and radium was called Radon (see appendix (1)). Subsequently, in precise usage, the term Radon has come to designate the symbol (Rn), the atomic number (86), mass number (222) and the most abundant of the 18 radioactive isotopes of the element Radon. Chemically, Radon is a noble gas. As such, it is similar, for example, to helium and neon. Like any other noble gas, Radon is colorless and odorless. If it is in the air, it is inhaled along with all other gases. It is also exhaled promptly, and when dealing with Radon alone there would be little reason for concern. The Radon hazards do not come primarily from Radon itself, but rather from radioactive products formed in the decay of Radon. These products called the “Radon daughters” that also radioactive and attach themselves to whatever they contact. The main health problems stem from inhaling of Radon daughters, or dust particles carrying Radon daughters, and subsequently lodging of the Radon daughters in the lung (Bodansky, Maurica, Robkin, and David, 1989)

Table (1.1): Radon isotopes, their chemical symbols and half-lives(EPA,2003).

No.	Radon isotope name	Chemical symbol	Decay series it belongs to	Half – life
1-	Radon	Rn^{222}	U^{238}	3.82 days
2-	Thoron	Rn^{220}	Th^{232}	55.6 sec.
3-	Actinon	Rn^{219}	U^{235}	3.96 sec.

A) Radon sources in homes

Rn^{222} is present in the natural environment because of radioactive decay of U^{238} . For intermediate decay a product follows the decay of U^{238} and produces Ra^{226} , is the direct source of Rn^{222} see Appendix (1).

Because Rn^{222} is a gas, it can readily travel through several meters of permeable soil before decaying.

The major sources of Rn^{222} in indoor air are:

- I) Soil gas emanations from soils and rocks.
- II) Off-gassing of water born Rn^{222} into indoor air.
- III) Building materials.
- III) Outdoor air.

Building materials generally contribute only a small percentage of indoor air Rn^{222} concentration. However, building materials may impart a greater Rn^{222} contribution when waste products from uranium mining were used to make concrete, concrete bulk. In some area with a high geologic Rn^{222} source outdoor gas concentration exceed several pci/l for short period(William, 2001).

B) Factors affecting indoor Radon concentrations :

Radon inside a house can be produced from several and different sources and the significance of every source changes from one place to another depending on the concentration of uranium, radium and Radon in that source. The ground under the house and building material generally contain uranium and radium. Radon released from these constituents is often the major source of Radon inside the house. The differences found in Radon concentrations among different houses stem more from differences in the rates of Radon entry than from differences in ventilation patterns(Harara,2007).

The Radon concentrations in a given house depend upon several factors:

I) Nature of the soil and rock

The radium content of the soil and rock under the building. Some of the houses with the highest Radon levels found to be built over a certain type of rock that is well known to have a high content of radium. Radon concentrations are strongly with construction type with structure made of wood usually exhibiting lower values than these derived from

geologic materials (Durrani and Radomir,1997).

II) The permeability of the surrounding soil.

A soil with high permeability will permit Radon to move more quickly through the pores to the surface and hence inside the house. A sandy soil is a good permeable where a clay soil is not (Willian and Anthony,1987).

The nature and extent of the openings between the house and soil. This with the previous two factors, determine the Radon entry rate. In general a house with a basement provides the greatest amount of house, soil contact and hence the greatest opportunity for Radon entry. A house with a crawl space generally provides the least contact between the building and the soil (Willian and Anthony,1987).

III) High level of the house

Radon concentration varies with height above the ground ranging from a maximum at the soil air interface to an immeasurably low value in the stratosphere, variation are quite strong in the first few meters above ground. So the basement (lower part of a house) has higher Radon levels than the upper part of a house. Radon concentration varies from one building to the other within the same location. It is also different from one floor to the other within the same building (Al-Kofahi et al.,1992).

IV) Ventilation rate

As Radon is a gas, the ventilation in the houses is an important factor affecting the Radon concentration. In houses with self-ventilation, weather conditions outside mean that the ventilation rate indoors is changeable. Ventilation rates depend on wind velocity outside, the air exchange rate and Radon level inside. Decreased ventilation rates are important causes of the high indoor Radon concentrations. It is discovered that several classes of pollution could occur indoors at higher levels. This is owing to the pressure of gas stoves in the houses, therefore with increasing the ventilation rate is there deceasing in the indoor Radon concentration. Among the different rooms in a house the cellar normally has the lowest air exchange rate and it also closest to the ground. The ground is the most powerful Radon source (Durrani and Radomir,1997).

The ventilation rate has three components. Infiltration refers to the uncontrolled leakage of air into the building through cracks and holes in the building shell. Natural ventilation is the flow of air into the building through open doors and windows. Mechanical ventilation is provision or removal of air by means of blowers or fans (Willian and Anthony,1987). Almost all homes have some Radon; the levels can vary dramatically

even between similar homes located next to each other. There are many factors; it is very difficult to predict the Radon level in a home. The only way to determine whether your home has Radon levels is to test for it.

V) Seasonal variation

The Radon concentration varies with time during the day, again the afternoon values are lower than the morning values (Thomas,1983). This variation depends on how people behave in houses; whether the doors and windows are open or kept closed; whether the kitchen fan is running and so on. There is also a seasonal variation of Radon levels. In summer, where the temperature is high or higher than winter, also the humidity changes from season to another (Willian and Anthony,1987).

It is also evident that each house has its own specific “life” of Radon. Therefore it is not possible to generalize and say that is enough to measure the Radon level in one house and believe that the neighboring houses have the same Radon level.

1.3.2 Man-made radiation:

Natural and artificial radiation sources are identical in their nature and their effects. The most significant source of man-made radiation exposure to the general public is from medical procedures, such as diagnostic X-rays nuclear medicine and radiation therapy. Some of the major isotopes used would be ^{131}I , ^{99}Tc , ^{60}Co , ^{192}Ir , ^{137}Cs , and others, Although all living things are exposed to natural background radiation, two distinct groups are exposed to man-made radiation sources, members of the public and occupationally exposed individuals (U.N.NRC, 2014).

1.4 Radon in Soil, Water and Air

Radon is found in all soils and rocks to some degree, but the amount can vary in different parts of the country and at different times of the year. It is formed in the ground by the radioactive decay of small amounts of radium which itself is a decay product of uranium. The gas rises to the surface and in the open air is quickly diluted to low and harmless concentrations in the atmosphere. However, once it percolates into an enclosed space, such as a building, it can accumulate to dangerous levels, depending on the concentration of Radon in the underlying soil and the construction details of the building. Radon may also be introduced indoors by way of ground water supplied from a well, or from building material containing traces of radium.

1.4.1 Radon in soil

Radon forms in rocks and soil that contain uranium or thorium. Rocks have generally been thought to be the major source, Radon production and migration in soil and bedrock define radon availability, while specific site and construction characteristics control the Radon transfer into houses. Radon moves into houses because of a negative pressure differential, and because of a large concentration gradient between the (house) building and bedrock or soil. The Radon concentration in houses is likely to relate fairly closely to that in the soil although there is no well established method of estimating Radon levels in individual dwellings based on soil Radon data. There are direct correlations between uranium, radium, Radon in soil gas, and indoor Radon concentrations. Also suggested that geology and soil gas Radon are useful indicators of indoor Radon concentration (Reimer, 1991).

The values inside buildings depend on structural characteristics, ventilation rates, aerosol concentration, central heating, building materials, and the habits of the inhabitants (Oliver, Whiteknights and Kharyat, 1999).

Hamed(2005) measured the Radon concentration in soil at North Gaza and the results obtained that the average value of Radon concentration in soil was 207.24 Bq/m^3 , ranging from $(23.48 - 584.15) \text{ Bq/m}^3$.

1.4.2 Radon in water

Radon can enter home through water systems. Water in rivers and reservoirs usually contains very little Radon, because it escapes into the air; so homes that rely on surface water usually do not have a Radon problem from their water. In big cities, water processing in large municipal systems aerates the water, which allows Radon to escape, and also delays the use of water until most of the remaining Radon has decayed. In many areas, ground water is used as the main water supply for homes and communities. Small public water works and private domestic wells often have closed systems and short transit times that do not remove Radon from the water or permit it to decay. This Radon escapes from the water to the indoor air as people take showers, wash clothes or dishes, or otherwise use water.

In areas where the main water supply is from private wells and small public water

works, Radon in ground water can add Radon to the indoor air (Otton, Gundersen and Schumann, 1992).

Harara (2007) measured the concentration of Radon in the ground water in southern part of Gaza Strip and the results obtained that radon levels in Rafah area ranges of values between 58 and 154 Bq/m³ with average value of 102.4 Bq/m³ and in Khanyounis area ranges of values between 22 and 132 Bq/m³ with average value of 47.8 Bq/m³. Certainly, these results indicate that the Radon concentration is relatively high, and this suggests to be remediated.

1.4.3 Radon in air

Radon moving through soil pore spaces and rock fractures near the surface of the earth usually escapes into the atmosphere.

In constructing a house with a basement, a hole is dug, footings are set, and coarse gravel is usually laid down as a base for the basement slab. Then, once the basement walls have been built, the gap between the basement walls and the ground outside is filled with material that often is more permeable than the original ground. This filled gap is called a disturbed zone.

Radon moves into the disturbed zone and the gravel bed underneath from the surrounding soil. The backfill material in the disturbed zone is commonly rocks and soil from the foundation site, which also generate and release Radon. The amount of Radon in the disturbed zone and gravel bed depends on the amount of uranium present in the rock at the site, the type and permeability of soil surrounding the disturbed zone, underneath the gravel bed, and the soil's moisture content (Otton et al.,1992).

Radon levels in **outdoor air, indoor air, soil air**, and ground water can be very different. Outdoor air ranges from less than 0.1 pCi/L to about 30 pCi/L, but it probably averages about 0.2 pCi/L. Radon in indoor air ranges from less than 1 pCi/l to about 3,000 pCi/L, but it probably averages between 1 and 2 pCi/L. The amount of Radon dissolved in ground water ranges from about 100 to nearly 3 million pCi/L (Otton et al.,1992).

Radon in soil air (the air that occupies the pores in soil) ranges from 20 or 30 pCi/L to more than 100 pCi/L; most soils in the United States contain between 200 and 2,000 pCi/L of Radon per liter of soil air (The National Average of Approximately 10kBq/m³ (270pCi/L) (Otton et al.,1992).

1.5 Units of radiation and radiation dose

There are common units used to measure radiation and radiation dose. We will define most of these units in brief: Becquerel (Bq) and curie (Ci): are common units used for radioactivity. The (Bq) is defined as: one disintegrate per second. Curie is equal 3.7×10^{10} disintegrations per second. The (Ci) is large unit so we usually use milli and micro curies or kilo and mega Becquerel's.

Due to that instruments which are not 100% efficient we are often use counts per unit time instead of disintegration,(Health physics,2010).

i) Exposure: Any ionizing beam passing through air causes ionization of the gas molecules and the formation of an electric charge.

$$\text{Exposure} = \frac{q}{m} \quad (\text{coulombs/kg}) \quad (1.1)$$

Where q : is the total electric charge produced and m is the mass of air. The unit of exposure are coulombs per kilogram ($c \text{ kg}^{-1}$); the old unit is Roentgen (Nazaroff and Nero, 1987).

ii) Exposure rate: Amount of exposure per unit time and the units of exposure rate is $c \text{ kg}^{-1} \text{ s}^{-1}$ (Nazaroff and Nero, 1987).

iii) Roentgen: Is a unit used to measure exposure in air and only for X-rays and Gamma rays. One Roentgen has energy to produce 0.000258 coulombs of charge by ionization in dry air. The Roentgen is limited in use at present, because roentgen is used only for gamma and x-rays and only in air (Max, 1995).

iv) Kerma (Kinetic Energy Release in Material):The amount of energy loss in a small air volume and the unit of kerma is Gray.

Kerma used only for high energy photons which is an important measure for radiation therapy and is not commonly used in diagnostic radiology(Nazaroff and Nero,1987)

v) Absorbed dose D: Is measure of the energy absorbed by a volume of material (air or tissue)

$$D = \frac{E}{M} \quad (1.2)$$

Absorbed dose in air may be identical to tissue because the average atomic number of air 7.6 which is very close to water and soft tissue and the absorbed dose measured by

J.Kg⁻¹ or gray (Gy) (Nazaroff and Nero,1987).

The probability of tissue radiation damage depends not only on the absorbed dose but also on the type and energy of radiation.

The effect of radiation type introduced as a radiation weighting factor w_R . The value of radiation weighting factor has been selected by the International Commission on Radiological Protection (ICRP) to represent of the relative biological effectiveness for inducing stochastic effects at low doses. The value of w_R are presented in the table(1.2) (Nazaroff and Nero,1987).

Table (1.2): The value of radiation weighting factor w_R

	Type and energy range	w_R
1	X and gamma – rays	1
2	Electrons and betas	1
3	Neutrons	5 – 20
4	Alphas and fission fragments	20

vi) Equivalent dose H_T :

The equivalent dose is the absorbed dose averaged over a tissue or organ and weighted according to the radiation type The equivalent dose is measured in savert (sv) (Nazaroff and Nero,1987).

Effective dose equivalent:

This quantity expresses the overall measure of health detriment associated with each irradiated tissue as a whole body dose. It's calculated by the relation

$$E = H_T \times W_T \quad (1.4)$$

A value of Effective dose equivalent is the overall risk per (Sv) of irradiating the whole body. The sum of the effective doses.

$$E = \sum H_T \times W_T \quad (1.5)$$

However for radiation dose we use many units to measure radiation absorbed dose, dose equivalent and exposure (Nazaroff and Nero,1987).

vii) Gray and rad: is a units used to measure absorbed dose relates to amount of energy absorbed by material and used for any type of radiation and any type of material, where 1 rad is equal to 100 ergs per gram and 1 Gray is equal 100 rad. These units are not used to describe the biological effects (Max,1995).

x) Severt and rem:

It is a unit used to measure a quantity called equivalent dose and this relates the absorbed dose in human tissue to the effective biological damage of radiation. Note that not all radiation has the same biological effect if the tissue has the same amount of radiation; S v depends on the quality factor (Q):

$$1 \text{ rem} = 1 \text{ rad} \times Q \quad (1.6)$$

$$1 \text{ Sv} = 100 \text{ rem} \quad (1.7)$$

So rem or Sv are units of biological risk (Max,1995) .

xi) Tissue weighting factor W_T :

The probability of tissue radiation damage depends not only on absorbed dose and type of radiation but also on the type of tissue. So there was a need to find a relation to combine type of tissue and probability of damage when exposed to the same equivalent dose. The weighting factor for important tissues can be easily obtained from (Nazaroff and Nero,1987).

1.6 Health Effects of Ionizing Radiation

The magnitude of the radiation absorbed per year due to natural or background radiation may provide a basis for a health risk to human body.

Effect of radiation: Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage. At low doses, such as what we receive every day from background radiation, the cells repair the damage rapidly. At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Cells changed permanently may go on to produce abnormal cells when they divide. In the right circumstance, these cells may become cancerous. This is the origin of our increased risk in cancer, as a result of radiation exposure (UNSCEAR, 2008).

1.7 Health risk of Radon

When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon (Po^{218} and Po^{214}) can interact with biological tissue in the lungs leading to DNA damage. Cancer is generally thought to require the occurrence of at the least one mutation (WHO,2007).

It is of great importance to assess the exposure to ^{222}Rn and its progeny in dwellings, especially houses, offices, schools, and universities for the purposes of quality control. Assessment of the risk can only be done with accurate information on the radon concentration levels to which the people are exposed (Magalhaes, Amaral, Sachett and Rochedo,2003), (Alenezy,2014). Investigations of natural radiation have received particular attention worldwide and led to extensive surveys in many countries (UNSCEAR,2000),(Al-Bataina,2000),(Popovic and Todorovic, 2006).

If we inhaled radon atom, the atom can disintegrate while it is in your lungs. When it disintegrates, it becomes polonium 218(Po^{218}), which is a metal. This metal atom can settle in your lungs, and over the next hour or so it will emit number of alpha particles, beta particles and gamma rays. It eventually turns into lead-210 (Pb^{210}) with a half-life of 22-years, which is fairly stable in this context. But now you have an atom of lead in your system, which cause its own problems. When an alpha particle strikes the chromosomes in a lung cell, it could alter the way that cell reproduces. Our bodies' immune system should recognize and destroy these mutant cells before they can multiply over the next 10 to 20 years into a recognizable cancerous growth. An increased frequency of lung cancer among miners had been attributed to exposure to radon in mines. On the basis of the pooling of results from large epidemiological studies, an increased frequency of lung cancer in the general population can now be attributed to exposure to radon in homes at elevated levels, specifically at concentrations greater than about 100 Bq/m³ (UNSCEAR,2012).

1.8 Statement of problem

In recent years there has been an increasing awareness in the radiation exposure of the general public .

This has generated an interest in indoor radioactivity measurements, since in many countries, the main source of radiation exposure occurs indoors.

This is motivated by the concern about the possible consequences of long term exposure to higher concentration ^{222}Rn and its short-lived products in air .

It is known that radon ^{222}Rn through its radioactive progeny can cause lung cancer and thus has become a public health concern. In addition, due to current wars that facing Gaza Strip, radiation evaluation should be detected .

Since no clear cut evidence of work have been performed to determine the radon concentration in the region of Rafah in southern Gaza strip, Therefore, we are in concern with radon concentration evaluation in this region.

1.9 Objectives

The main objective of the study is to investigate the natural radiation pollution in air of the southern part of Gaza strip(Rafah), particularly the measurements of radon concentration in air of houses.

This study will provide a framework for future studies that may be needed for environmental studies point of view.

It is required to find out the relationship between radon concentrations and health risks and many diseases that spreading in the country. Also, some bases for radiation protection countermeasures are recommended too. This includes action level recommendations for the existing houses and for future housing architect design. Moreover, with this study we also aim to create interest and increase public awareness about the radon hazard in the community.

Chapter 2

Literature Review

Chapter 2

Literature Review

2.1 Area of study

Rafah is a Palestinian city and refugee camp in the southern Gaza Strip. It is the district capital of the Rafah Governorate, located 30 kilometers (19 mi) south of Gaza City. Rafah's population of 164,000 is overwhelmingly made up of Palestinian refugees. Rafah camp, Tall as-Sultan camp and El Genena form separate localities. See figure (2.1) (Palestinian National Information Centre, 2016).

Rafah area is located at longitudes $34^{\circ}15'34''$ E, latitudes $31^{\circ}17'13''$ N and elevation above sea level: 79 m = 259 ft

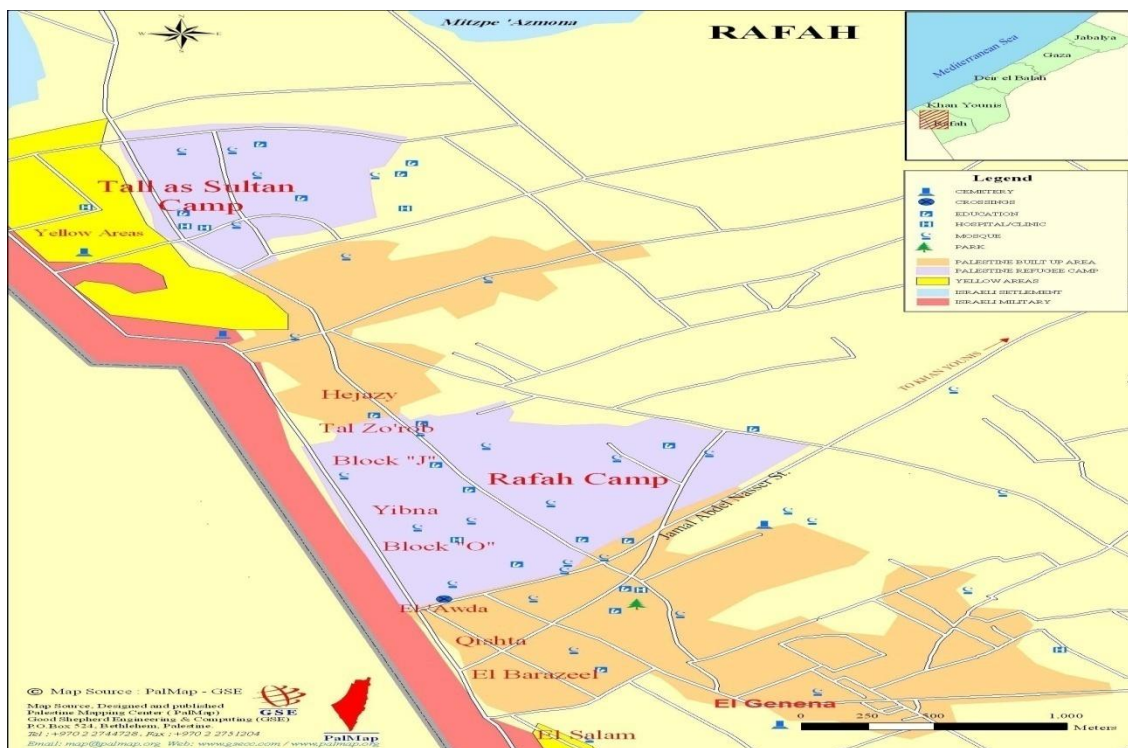


Figure (2.1): Map of Rafah(Palestinian National Information Centre ,2016)

I) Climate and rainfall

Gaza strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the semi- humid Mediterranean climate along the coast.

The average mean Daily temperature in Gaza Strip ranges from 25° C in summer to 13° C in winter. The average annual rainfall varies from 450 mm/year in the north to 200 mm/year in the south. which is the main conventional source, became insufficient to

refresh the groundwater system (Harara,2007).

Rafah have a semi-desert climate, in despite of its proximity to the Mediterranean, and average temperatures between 30 degrees in summer and 10 degrees in winter, with an average rainfall of 250 mm. Most of the rainfall occurs in the period from October to March (Abu Mayala and Aish, 1997).

II) Geology of Gaza Strip

Geology of Gaza strip was obtained from oil and gas exploitation logs up to depth of about 2000m drilled by Israel and from the wells drilled during the Coastal Aquifer Management project(camp).Geology of the study area consists of a sequence of geological formations ranging from upper Cretaceous to Holocene .This sequence is gradually sloping westwards(PWA,2000) as shown in the figure (2.2)

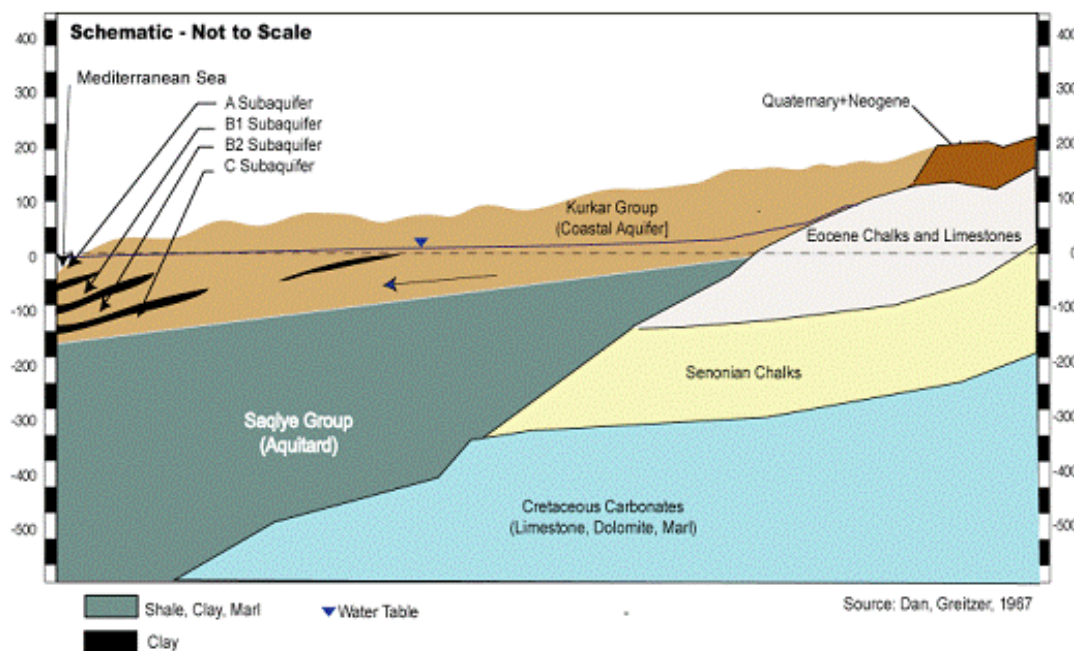


Figure (2.2): The Geological cross-section in the Gaza strip(Harara,2007)

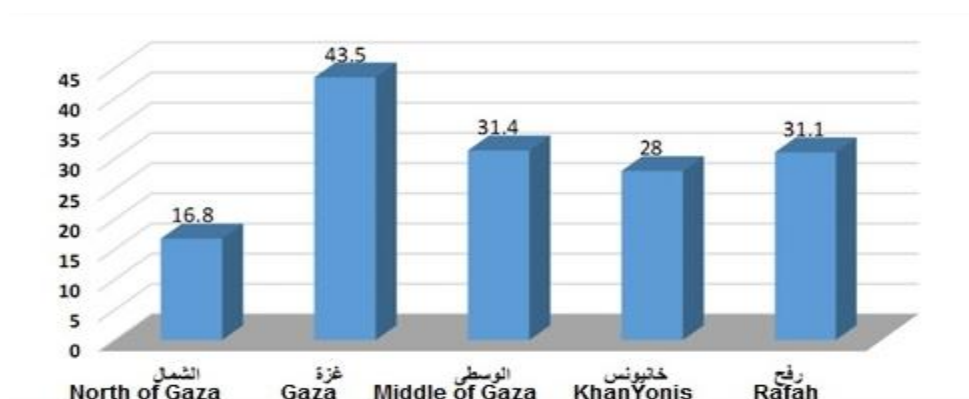
The surface of the Gaza strip is simple and exposures are limited. It is formed of a series of alternating ridges. These ridges consist of clayey sands stone and silt which referred to as continental kurkar or Jarwal . The coastal 1-4 km wide along the Mediterranean sea is covered with calcareous sand dunes,(Sersawy,2007).

III) The Statistics:

The population findings: The findings show that the total number of Rafah Governorate population on the midnight of December 1, 2007 was 173,539 people, including 87,425 males and 86,114 females. The male/female sex ratio totaled 101.5 males per 100 females, The Palestinian society of Rafah Governorate is still a young society. The number of the people aged 0-14 years in Governorate totals 75,419 or 44.2% of the total Governorate population. The number of people aged 15-64 is 88,273 or 51.7% of the total number of Governorate population. The number of the rest of the population whose age is 65 years and over totals 4,537 of Governorate population or 2.7% of the total Governorate population. 1.4% of Governorate population have unstated ages (PCBS, 2012, pp. 27-28).

In Gaza strip about 3.646 cases of cancer reported in 1995-2000, 1750 in male and 1896 cases in female. The incidence rate per 100,000 population was 59.9 in general population 316 cases from the total number of cancer is lung cancer, about 251 deaths were reported: 206 in male and 45 in female. The deaths is distributed on Gaza strip as: north Gaza 39 death, Gaza city 107 deaths, midpoint 35 death: Khan younis 44 deaths and Rafah 26 death. In male bronchus and lung cancer is the first leading cause of cancer mortality 19.9% of all cancer mortality, the main reason to cause Lung cancer is smoking and radon gas (Awad and Abu Arqoub,2002).

Recently, lung cancer is the third most prevalent type in the Gaza Strip, and has been recently monitoring 522 new cases in the period between 2009 to 2014, including the percentage equivalent of 7.3% of the total cases. Figure (2.3) illustrates the rate of incidence of lung cancer, according to the governorates/100,000(MOH-PHIC,2015, pp. 18-19).



Figure(2.3): The rate of incidence of lung cancer, according to the governorates/ 100,000

This indicate that there is an increase of lung cancer in Gaza strip, and it is vital important to study the reasons of this elevation. this could be enable us to provide a good remediation when Radon concentration is determined.

2.2 Indoor Radon concentrations in different countries

There is no doubt about Radon being a lung carcinogen for humans. All major international organizations that have examined the health risks of Radon agree that it is a lung carcinogenic. For instance, in the U.S.A., the Environmental Protection Agency (EPA) and the National Cancer Institute (NCI) have independently placed that numbers at about 15,000 lung cancer deaths each year are attributed to Radon. Because of the health risks of Radon and its decay products, many scientists examined Radon concentrations in different places in overall the world. They used various experimental and technical possibilities that are available to measure the Radon concentrations indoors. These procedures will be discussed later. Recent surveys in a number of countries in the European Communities (EC) have shown that the average Radon level ranges from about 20 to 50 Bq/m³, with some countries having Radon levels of several hundred to a few thousand Bq/m³ (Durrani and Radomir,1997). This depends strongly on the factors of Radon concentrations. On the other hand many countries set (action levels) based on the Radon concentration alone. (An action level is the maximum concentration of Radon permitted), before some action is deemed necessary to reduce the concentration. For example, the EC (1990) has recommended the following action levels: 200 Bq/m³ for new homes and 400 Bq/m³ for existing homes. EPA in U.S.A(1987) recommended that if a short-term screening measurement result is above 140 Bq/m³, a follow-up measurement is needed to determine the long-term average concentration. If the long-term average is still above 150 Bq/m³, action is recommended to lower the concentration (Stephen, Annie and Nigle,1995). The Radon concentration was found mainly to depend on the ventilation rate. Variation of the inverse of the ventilation rate with the concentration of Radon daughters in the different high-rise buildings.

Muhsiz, Nilgun, and Berna (1993) have measured indoors average Radon concentrations in more than 400 houses **in Istanbul** City in Turkey. The average

Radon concentrations vary between 10 to 260 Bq/m³ and the mean value was 50 Bq/m³. They reported that the bedrooms have relatively higher Radon concentrations than living rooms and Radon concentrations in the basement floors were higher than those in the upper floors. This was attributed to elevated level in bedrooms to the exhaled Radon of the sleeping person and poor ventilation of the bedroom (Muhsiz et al. ,1993). In a survey made **in Singapore**, 100 detectors were used for measure Radon concentrations of the living room and the bedroom to show that Radon concentration in the two rooms could be different due to variation in the ventilation rate. Radon concentration ranges from 2.4 to 54.89 Bq/m³ and arithmetic mean was found to be 11.95Bq/m³ (Stephen et al.,1995). Measurements were made in 55,000 randomly selected houses in 38 states divided into 225 regions in Unites States, to identify houses with screening level of Radon. 24 regions were identified as having the highest Radon concentration: with 78.4% above 74 Bq/m³; 57.3% above 148 Bq/m³; 31.7% above 296 Bq/m³; and 8.6% above 740 Bq/m³. An extremely high Radon level, exceeding 410 kBq/m³, has been measured in the basement of a house in Prescott in the state of Arizona (Durrani and Radomir,1997). Some locations in Brazil have been recognized worldwide as high level natural radiation areas. However, Radon concentration was ranging from 600 to 900 Bq/m³ in living areas and bedrooms. The high values obtained from indoor Radon concentrations can be attributed to the combination of local geology, building materials used, and type of structure and nature of ventilation used in some houses (Peter, Schneider, Bayer, and Trugenberger,2002). **In Ireland** dwellings, the Radon measurements were carried out in 11,319 houses throughout the country. The Radon levels varied from 10 to 1924 Bq/m³, with average indoor Radon concentrations of 89 Bq/m³. It can be estimated that approximately 91,000 houses throughout the country have indoor levels in excess of 200 Bq/m³(Werner, Mehdi and Anton ,2002).

In Saudi Arabia, Radon concentration in houses in Najran region was measured, the average concentration value measured in this study is 49 ± 14 Bq/m³(Al-Awad , 2008).

In Jordan (340 dwellings in Irbid region), it has been found that Radon levels vary between 3.0 to 163.9 Bq/m³ with an average value of 33.28 Bq/m³. Also measurements indicated that the highest Radon concentration is found to be in basement floor and in the bedrooms(Al-Kofahi et al.,1992).

In West Bank in Jenin, The indoor radon concentration levels were found to vary from 26 to 258 Bq/m³, with an arithmetic mean and standard deviation of 76.6 and 16.2. The estimated effective dose to the population was found to vary from 0.69 to 2.12 mSv/yr, with a mean of 1.15 mSv/yr (Abu Samra et al.,2014).Also in Bethlehem the Indoor radon level measurements were carried out in 42 dwellings ,the results of indoor radon levels and the annual effective dose in houses were found to vary from 26 - 611 Bq/m³ and 0.65 - 14.1 m Sv y⁻¹, with average values of 117.0 Bq/m³ and 2.95 m Sv y⁻¹, respectively,(Leghrouz , 2013).

Recently, primary survey of Radon concentrations was carried out throughout north and middle zone of **Gaza Strip** dwellings by Yassin and Steck (1999), the measurements show that Radon concentration ranges from 22 to 43 Bq/m³ with arithmetic mean 34 Bq/m³. Rasass(2003) found in his study that the indoor radon concentration in the middle zone of Gaza Strip in all region was 37.83 Bq/m³ (1.02 pCi/l) with a range of values between 13.36 and 83.82 Bq/m³ (0.361 and 2.265 pCi/l) and a maximum value of 97.06 Bq/m³ (2.62 pCi/l) with average standard deviation of 11.23. Sersawi(2007) found in his study that average number of tracks/cm² was detected at all the regions in Gaza city was 39 Bq/m³ (1.1 pCi/l) with a range of values between 9.5 and 80.5 Bq/m³ (0.24 and 2.18 pCi/l), average standard deviation of 17.01Bq/m³ and a maximum value of 105 Bq/m³ (2.8 pCi/l).

2.3 Methods to reduce Radon concentration indoor:

There are several methods to reduce radon concentration; one is by removing the source of radon if it was possible like the waste of uranium mines that are close to residential areas, or sealing cracks and other openings in the foundation which limits the flow of radon into homes, thereby making other radon reduction techniques more effective and cost- efficient. Also, good ventilation system is recommended for controlling radon daughters to below the exposure limits by using a vertical fan to

blow air outdoors or simply through the ventilation of buildings through windows (EPA, 2010).

To avoid high concentration of radon gas in buildings that will be built in the future we advise not to use building materials that release large amounts of this radioactive gas and to avoid the construction of buildings in areas with high radioactive concentrations.

2.4 Motivation of our study

In general, natural radiation may be one of the most dangerous pollutants in our environment. Also, all building material, in Gaza strip, is imported through occupied Palestine and have never been monitored to ensure compliance with relevant standards. In addition, building designs do not take radon risk into consideration and no public awareness exists.

Extensive measurements have been done in the world showing that radiation in homes increases Lung- cancer risk for general population, especially, those who spend a majority of their time at home. Here in Gaza we have no information about radiation concentrations. Where women and children under six years old (25% of the total population) spent more than 90% of their time at home(Sersawi, M.,2007). The birth rate will increase the problem in the future. Our main interest of our current research is to find out the relationship between radiation concentration and health risks of lung cancer, since no serious attention has been given to health risks due to radiation exposure

This motivated us to pursue this survey throughout Rafah city in southern Gaza Strip, specially no studies have done before in this region to evaluate the concentration of Radon level.

Chapter 3

Experimental Setup

Chapter 3

Experimental Setup

3.1 Measurement device location selection

The measurements of Radon concentration can be divided into two major classes namely **passive method**; when the Radon concentrations are measured under natural conditions, Radon entering the detection volume by more diffusion, don't need power to function , or **active method**, which involves the pumping of gas into or through a detecting instrument, require power to function(Durrani,S.and Radomir,1997). Radon tests fall into two categories: **short-term tests** (screening) which are for a period less than three months and **long-term tests** which are covering periods longer than three months. The two most popular, commercially available Radon detectors are the charcoal type and alpha track detector. The charcoal type is always a short- term test but alpha track detector may be either short or long-term. Both kinds are designed to be exposed to the air inside home for a specific period of time. Then, they are sent to a laboratory for analysis.

Let us now examine the various experimental and technical methods of measuring Radon concentration in the environment.

3.1.1 Passive devices

The passive method has several advantages over the active method. The passive technique is now widely used by scientists and researchers on large scale. This technique has also attained the status of commercial use throughout the world. In the case of direct measurement of the radiation, the detection sensor is usually placed inside a container (dosimeter) that has an opening to let Radon enter it. The container is used meantime to protect the detector and to make room around the detector for a sensitive volume large enough so as to have as many alpha particles produced and detected in as short time as possible usually for several months. The various detectors that can be used for Radon concentration measurements are:

I) Electret detectors

Electret detector has the ability to store information over relatively long periods of time, it is independent of humidity in its environment, and is easy for reading. Electret detector is a piece of dielectric that exhibits a permanent electrical charge.

This charge produces a strong electrostatic field, which is able to collect ions of the opposite sign and the total charges of the electret decrease. An electret dosimeter is made of a steel can, on the inside top of which the electret detector is fixed. At the bottom of the can a small inlet allows the Radon gas to enter the assembly through a filter. When Radon decays it produces ionizing particles that in turn produce ions within the can. These ions and the total charges of the electret detector are collected. The charge deposited is calculated from which Radon concentrations can be determined. But its response curve does not efficiently cover the very low or very high dose, also it is sensitive to normal gamma radiation background (Durrani and Radomir,1997).

II) Charcoal adsorption detectors

Radon, like a number of other gasses, can be adsorbed on charcoal. This property has been used to develop a practical detection system in which Radon gas is accumulated in a bed of charcoal then the gamma ray activity from the decay of Radon daughters is counted (Bodansky et al.,1989).

Charcoal adsorption detector is a passive low cost screening method for measuring indoor Radon concentrations. For this method, an airtight container with charcoal is opened in the area to be sampled and Radon in the air adsorbs into the charcoal adsorption detector by diffusion. The detector is deployed for 2 to 7 days. At the end of the sampling period, the container is sealed and sent to a laboratory for analysis. After exposure, scintillation fluid is added to the vial and Radon concentrations is determined by the alpha and beta decay of Radon and progeny when counted in a liquid scintillation spectrometer. But charcoal adsorption detectors are sensitive to drafts, temperature and humidity(Marssim,1997).

III) Thermoluminescent Detectors (TLDs)

Ionizing radiation can cause atomic or molecular disturbance in some materials such that material emits light when heated. TLDs for ionizing radiation are based on this property. TLD chip is exposed to α and β particles and gamma rays that are emitted by the Radon and its decay product (Bodansky et al.,1989).

In the case of Radon detector, Radon is allowed to enter a detector volume containing the TLD. A metallic plate is placed at a short distance in front of the TLD. This plate can either be electrically charged for better collection efficiency, or not. Radon daughters deposit on the plate and ultimately decay, thus producing

energy storage in the TLD. After proper exposure to Radon rich atmosphere, the TLD is recovered and read in a TLD apparatus. But the data analysis is not always very simple, depending on the type of used TLDs. In commercially available devices the data analysis is made automatically (Durrani and Radomir,1997).

IV) Solid State Nuclear Track Detectors (SSNTDs)

SSNTDs as a passive technique which have several advantages; low cost, long term method, most widely used for measuring Radon and can be used for site assessment both indoors and outdoors. SSNTDs are sensitive to alpha particles in the energy range of the particles emitted by Radon. SSNTDs are largely insensitive to beta and gamma rays. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light. They of course do not require an energy source to be operated since their detecting property is an intrinsic quality of the material they are made of , (Durrani and Radomir,1997). There are three types of commercially available SSNTDs are:

- a) Polyallyl - Diglycol-Carbonate ($C_{12}H_{18}O_7$) was known as CR-39.
- b) Cellulose Nitrate ($C_6H_8O_8N_2$) was known as CN-85.
- c) Plastic track detector known as CR- 115

CR-39 is a better detector as compared to other detectors used for radon concentration measurement (UNSCEAR,2010).

3.1.2 Active devices

The active part for detecting Radon, or Radon daughter products, is an electrical or electronic device in general. Measurement technique is usually either pumped from the environment or extracted by means of a gas or liquid, sampling achieved by the suction action of pumps, syringes, pistons, etc. (require power to function)Where, Radon is pumped, the gas flow passes through the electronic meter to the outside of the equipment. Direct scintillation can also be used for measuring Radon levels by means of forcing air through the detector. The air is bubbled through liquid scintillation solvent where the Radon is dissolved and air passes through. Radon concentration is thus continuously measured (Durrani and Radomir,1997). In this method Radon concentration measured over shorter periods. However, the measurements are not valid tests for whole house Radon concentrations and should not be used to make mitigation decisions (EPA,2002).

3.2 Fundamental characteristics of detectors

The fundamental characteristics of detectors are:

3.2.1 Sensitivity

The sensitivity of a detector can be viewed as the capability to produce a useful signal for a particular radiation and its energy. Detectors are usually designed to be sensitive to a specific type of radiation within a given energy range. It therefore follows that there is no detector that can be sensitive to all types of radiation and all energies. Some of the parameters that influence the sensitivity of a detector are the detector mass and the cross section which determine the probability that an incident radiation will transfer energy to the detector in the form of ionization. For charged particles, even detectors of low density and small volume will usually have some ionization produced in its sensitive volume (Tscla,2000).

3.2.2 Efficiency(σ)

Generally the efficiency related the actual registered events by the detector to the events emitted by the source. Radiation detection is generally divided into **two** types: 1) Absolute efficiency (σ_{abs}), is the fraction of events emitted by source that is actually events by the detector (det.),

$$\sigma_{abs} = \frac{\text{Events recorded by det.}}{\text{Events emittedby source.}} \quad (3.1)$$

This efficiency is dependent on the properties of the detector and the design of the counting geometry,

2)The intrinsic detection efficiency (σ_{int}), is defined as the fraction of the events actually incident on the detector that are recorded.

$$\sigma_{int} = \frac{\text{Events recorded}}{\text{Eventsimping on the det.}} \quad (3.2)$$

This efficiency is a basic parameter of the detector. It is independent of the source and detector geometry. Also, it is a function of the type of radiation, detector material, and the physical thickness of the detector in the direction of the incident radiation (Tscla, 2000).

3.3 Measurement technique

The most common device for the measurement of Radon concentration inside houses and potential alpha energy concentration (PAEC) is the passive diffusion Radon dosimeter containing solid state nuclear track detector (SSNTD) CR-39. This type of detector is used throughout the present work. The dosimeter is composed of a plastic cup with a circular hole of diameter d in the center of the lid and depth h ($d=5\text{cm}$, $h=7\text{cm}$) as shown in the figure (3.1). A piece of dimension ($L=1\text{cm}$, $W=1\text{cm}$) of CR-39 is fixed to the bottom of the cup.

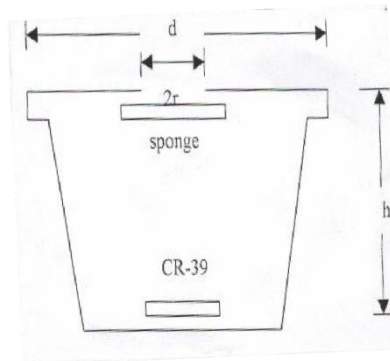


Figure (3.1) :Passive diffusion Radon dosimeter

This detector is exposed to indoor environment of a house for a period of time. The detectors are then collected from the houses and chemically etched. Then number of tracks per unit area are observed and counted under a microscope. Finally, from the track density the Radon concentration in (Bq/m^3) is determined.

3.4 Distribution technique

one hundred and fifty (150) dosimeters, were prepared and distributed inside the houses of Rafah in the southern of Gaza strip. These houses are chosen to be representative of the whole region. Our sampling strategy was to distribute the dosimeters in houses located at different geographic parts of the region. Moreover, houses built of different materials (see appendix 2). Like (stones and concrete), (stone and zinc) and (stone and spestos) were selected: a first group of 50 dosimeters was distributed inside Rafah camp(Balad), a second group of 50 dosimeters placed inside Tal El Soltan, finally a group of 50 dosimeters distributed inside El Genena. The detectors were placed in a room (Bed room, Kitchen and living room) where the occupants of the house spend

most of their time. The detectors were either hung on an interior surface or placed on a horizontal surface so that it was exposed to room air. They were not installed near any heat or air conditioning source and were not dusted. It has been pointed out that strong and uncontrolled variation in efficiency for detectors of alpha particles emitted by Radon and its decay products were observed in detectors exposed to solar light. Therefore, the detectors must be protected from sunlight.

The detectors were left in the houses for a period of three months, (from June to August of 2016).

3.5 Track chemical etching

The etchants most often used for organic polymers are aqueous solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH). The parameters most important for control of the etching speed of the detector are: the concentration of the etchants, etching time and temperature (Durrani and Ilic,1997)

3.5.1 Suitable Molarity (Concentration of the Etchants) of NaOH

To find out the suitable molarity of sodium hydroxide NaOH (concentration of the etchant), fifteen (15) dosimeters were exposed to ^{226}Ra (Radon source) of activity 800 Bq/m³ for ten days. Then the collective detectors were chemically etched using different values of molarity of NaOH at constant temperature 70⁰C and constant etching time (6 hours). The number of tracks per units area of 1cm² were counting using an optical microscope with power of (40x10).Figure (3.2) shows that the variation of the track density (number of track/cm²) against a molarity of NaOH(Rassas,2003).

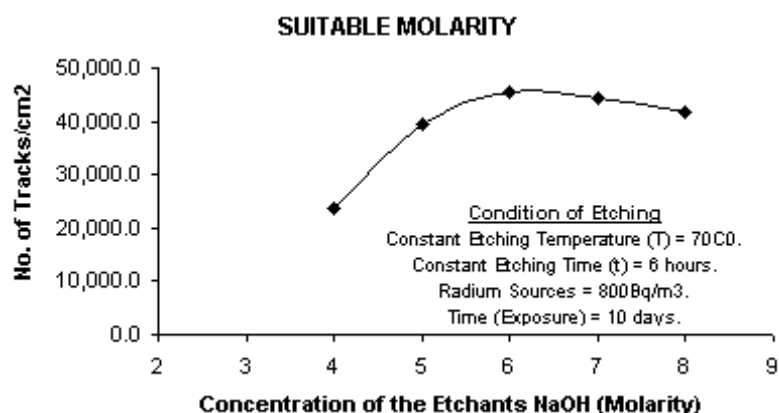


Figure (3.2): Relationship Between Track Density and Molarity(Rassas,2003)

The maximum number of the track density was found at 6M of NaOH, where a clear track observed. As the molarity of NaOH increased greater than 8M, the detectors were found not valid for track counting and dissolved.

3.5.2 Suitable Etching Temperature

To find out the suitable etching temperature, we are also repeated the calibration for another detectors. Then the collective detectors were chemically etched using different values of etching temperature at constant etching time (6h) and constant molarity (6M)(Rassas,2003). The number of tracks per units area of 1cm² were also counting using an optical microscope with power of (40x10).

Figure (3.3) shows that the variation of the track density (number of track/cm²) against a temperature(T).

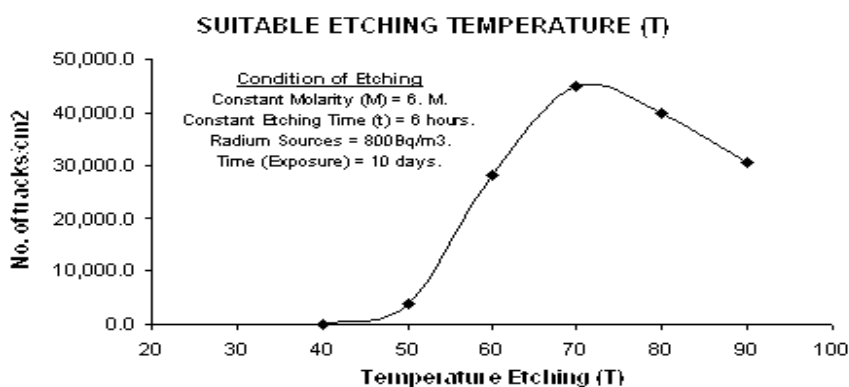


Figure (3.3): Relationship Between Track Density and Etching Temperature (T)(Rassas,2003).

The maximum number of the track density was found at 70 C⁰ of, where a clear track observed. As the temperature (T) of NaOH solution increased greater than 70C⁰– 72C⁰, we notes the tracks of detectors was large diameter and small track density. After these

two steps we took the temperature at 70 c, concentration of NaOH (6M) and time (5-6) hours as the best factor for chemical etching.

3.6 Determination of Radon concentration

The solid state nuclear track detector technique is one of the most often used techniques for the measurement of Radon. Radon concentration (C) in surrounding air is measured in terms of Bq/m³, since the most regulatory reference levels are specified in this unit.

Determination of Radon and its daughter's concentrations (C) throughout Gaza Strip are carried out using the following equation (Khader,1990).

$$C(\text{Bq} / \text{m}^3) = \frac{C_o(\text{Bq} \cdot \text{d} / \text{m}^3)}{\rho_0} \left\{ \frac{\rho}{t} \right\}_{\text{det.}} \quad (3.3)$$

Where,

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

ρ₀ =track density (number of tracks/mm²) of detectors exposed to ²²⁶Ra,

ρ =track density (number of tracks/mm²) of distributed detectors,

t= exposure time (days) of distributed detectors.

Simply, a number of dosimeters were exposed to a known dose of ²²⁶Ra (Radon source) for a period of time. Then those dosimeters were collected and treated to chemically etching. The average numbers of tracks/m² were observed. These detectors were considered as a calibration standard (Khader,1990).

Similar method is also obtained for track detectors techniques to determine the calibration constant (factor). This is derived by dividing the track density by the total exposure of Radon source. Then the equation (3.3) for Radon exposure becomes as follows :

$$C(\text{Bq} / \text{m}^3) = \frac{1}{k} \left\{ \frac{\rho}{t} \right\}_{\text{det.}} \quad (3.4)$$

where k is called the calibration factor in terms of (track.mm⁻²/Bq.d.m⁻³) or a calibration coefficient was determined experimentally.

3.7 Calibration factor (k)

The calibration process that made for dosimeters used in this survey prepared and exposed to radon source, four dosimeters were exposed for 30 days of ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3 . It gives 572 pCi.d/l ($2.12 \times 10^4 \text{ Bq.d/m}^3$) concentration for the total exposure done by Rassas(2003) in the physics laboratory, then reversed calibration constant ($1/k$) was found to be ($8.45 \times 10^{-4} \text{ Bq.d/track.m}$) the overall uncertainty in this calibration was estimated to be $\pm 10\%$ (Peter, et al.,2002). Substituting by reversed calibration constant in equation (3.4) then,

The above equation was used to determine the Radon concentration (C) throughout the present work

$$C(\text{Bq} / \text{m}^3) = 8.45 \times 10^{-4} \left\{ \frac{\rho}{t} \right\}_{\text{det.}} \quad (3.5)$$

For example, consider that there are 9 tracks/mm^2 (average value), where the dosimeter exposed for a time period of 90 days. So the Radon concentration would be:

$$9 \text{ tracks/mm}^2 \equiv 9 \times 10^6 \text{ tracks/m}^2$$

$$C = (8.45 \times 10^{-4}) (9 \times 10^6 / 90) = 84.5 \text{ Bq/m}^3$$

So, the observed 9 tracks/mm^2 corresponds $\approx 84.5 \text{ Bq/m}^3$ Radon concentrations.

Chapter 4

Results and Discussions

Chapter 4

Results and Discussions

4.1 Background

Passive diffusion Radon dosimeters containing CR-39 solid state nuclear track detectors of good quality were used in this survey. Our sampling strategy was to distribute the dosimeters in the buildings in the three district regions of Rafah city (Tal EL Soltan ,Rafah Camp(Balad) and El Genena). These dosimeters were distributed in a bedroom, living room or kitchen(three dosimeters for each house). Moreover, buildings built of different materials are considered in the present study like (stone and spestos) and (stone and concrete).High levels of the buildings are also taken into account, where the radon concentrations is strongly dependent. (See appendix 2).

4.2 General results

The collected detectors were chemically etched (see previous section 3.5). Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 4 distinct regions were observed, through the area (1mm²) (see figure(4.1)), the average number of tracks/mm² was found. By using equation (3.5) the Radon concentrations were determined over the different region in the study area of this survey. Table (4.1) illustrates the minimum and maximum concentrations of Radon that determined from different groups of regions. Standard deviation (S. D.) is also calculated and listed in the table.

The arithmetic mean of all measurements of Radon concentration performed at all the region of Rafah city was 73.8 Bq/m³ (1.99 pCi/l) with a range of values between 16.5 and 150.4 Bq/m³ (0.44 and 4.06 pCi/l) with average standard deviation of 15.1, the average of the obtained indoor radon concentration was below the indoor radon concentration action level (148 Bq/m³) as recommended by Environmental Protection Agency (EPA),while Rassas(2003) found that the radon concentration in the middle zone of Gaza Strip in all region was 37.83 Bq/m³ (1.02 pCi/l) with a range of values between 13.36 and 83.82 Bq/m³ (0.361 and 2.265 pCi/l) and a maximum value of 97.06 Bq/m³ (2.62 pCi/l) with average standard deviation of 11.23,also Sersawi(2007) found that the arithmetic mean of all measurements of Radon concentration performed at all the region of Gaza city was 39.12 Bq/m³ (1.06 pCi/l) with a range of values

between 9.5 and 80.5 Bq/m³ (0.26 and 2.18 pCi/l) and a maximum value of 105 Bq/m³ (2.83 pCi/l) with average standard deviation of 17.1, Abu Samra(2014) found that the indoor radon concentration in the building of Arab American University of Jenin(AAUJ) varied from 26 to 258(Bq/m³)with an arithmetic mean and standard deviation of 76.6 and 16.2(Bq/m³),Al-Janabi(2003) measured the Radon concentration in Irbid Governorate in Jordan. He found that radon concentration in the dwelling was about 38 Bq/m³ in Al-Rafeed Village.

In our study, the existence of some readings above the action level concentration(148 Bq/m³) that recommended by EPA in some houses was mostly due to the bad ventilation rate that appeared in the questionnaire. The overall uncertainty of these measurements was estimated to be ±10%. In some cases, only one measurement per building was made. However, it should also be taken into account that one result from a certain floor rooms does not necessarily represents the main Radon level of whole building.

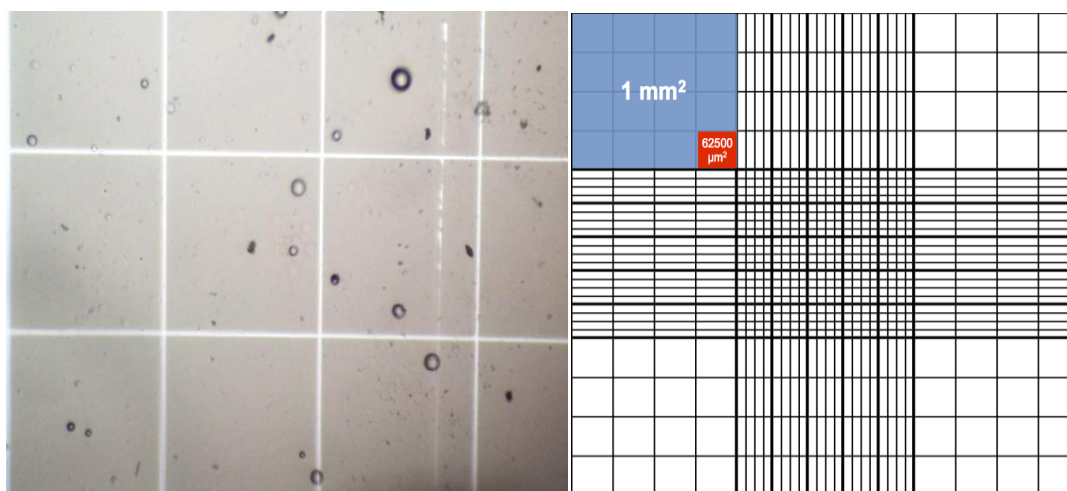


Figure (4.1): Tracks of alpha particles emitted by Radon in a CR-39 detector. One viewing field from the microscope has the area of about 1 mm² using a slide of depth 1/10 mm shown beside.

Table (4.1): Radon concentration in each region of present study

Location	No. of detectors	Ave. C(Bq/m ³)	Min. C(Bq/m ³)	Max. C(Bq/ m ³)	S. D. (Bq/m ³)
Tal El Soltan	50	75.6	23.5	159.6	13.4
Rafah Camp(Balad)	50	73.2	21.1	180.7	16.8
El Genena	50	72.6	16.5	169	15.1
Average value(Rafah,2016)	Sum=150	73.8	20.4	169.7	15.1
Average value(Sersawy Gaza,2007)	180	39	9.5	80.5	17
Average value(Rassas Middle Gaza,2003)	500	37.8	13.4	83.8	11.2

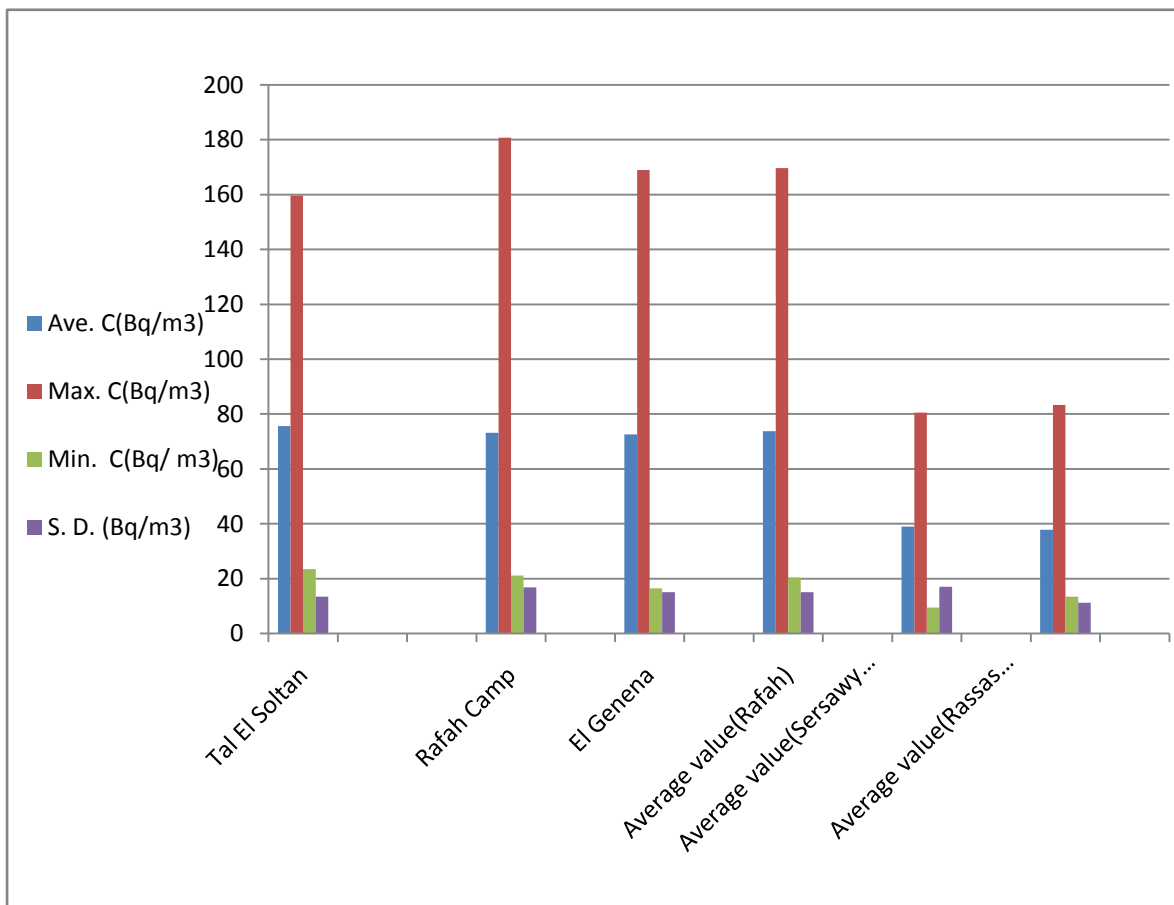


Figure (4.2): Radon concentration in each region of the present study in comparison with previous studies.

Figure (4.2) illustrates that the average Radon concentrations of the three regions (Tal El Soltan, Balad and El Genena) are almost equivalent. The results indicate that the difference between the minimum and maximum Radon concentration in each region is very high. This large variation in these regions is mainly due to the difference in the ventilation volume, different types of these locations in building (bedroom, living room, kitchen) and height level rise of building (basement, first floor, ... etc), different materials of building like the stone and spostos, stone and concrete... etc. Some of the buildings have their windows closed all the time, most of them have the windows opened for a few hours a day. In our sample of the region, about 38% have their windows opened for more 8 hours per day. This indicates that the difference in Radon concentration is due to different ventilation in the region of study.

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

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

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

Table (4.2): Radon concentrations variation with the level of the houses.

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

As shown in table (4.2) the Radon concentrations vary from one floor to another, and the basements are the highest Radon concentrations in all locations. This dependence demonstrates that Radon levels vary from floor to floor of the Tal El Soltan, Rafah

Camp and El Genena buildings. In these results, the Radon concentrations determined are mostly due to the contribution from the soil located under the building, and ventilation. The highest Radon concentration values were observed in the basements and decreases in the above floors due to increase in air movement.

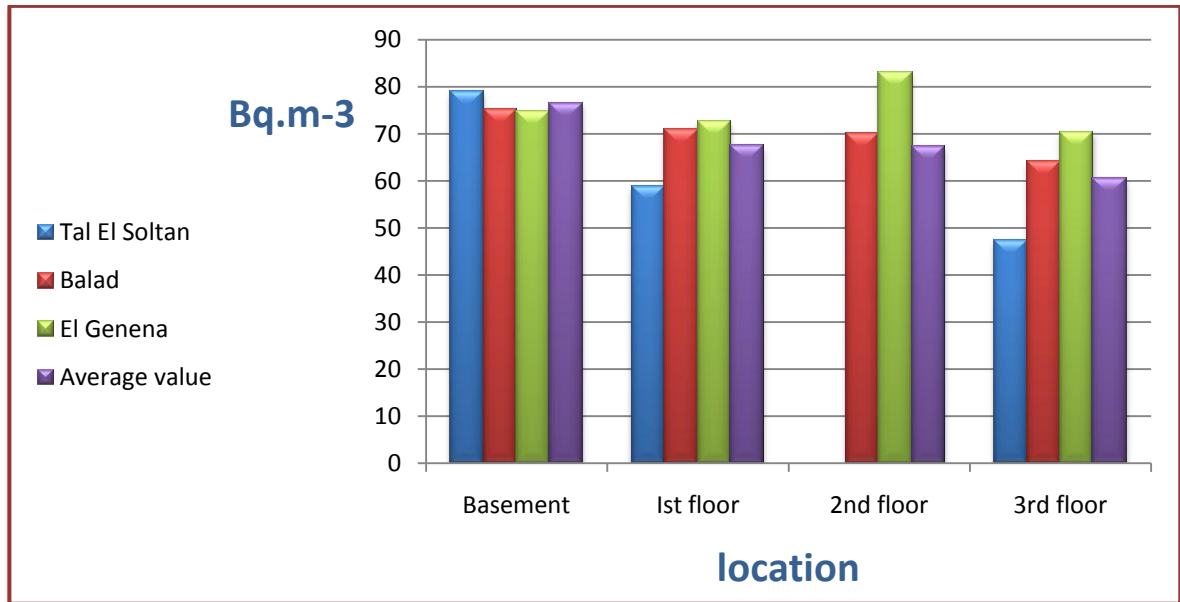


Figure (4.3): Radon concentrations variation with the level of the houses.

Figure (4.3) describes the histograms of Radon concentrations for various floors in these building locations. It can be seen that Radon levels inside the basement floors are the highest Radon concentrations in all locations. The rooms in these basement floors have small windows or less opening windows and their ventilation is poor because the buildings are close to each other, while rooms in the other building floors have large windows and ventilated better than in basement.

4.4 The variation of Radon concentrations with the materials of the houses

The determination of Radon concentration and its decay products in indoor air has become very important, since the main level of these measurements carried out in the different building material of detached built houses. The data describing the characteristics of the selected houses in only three regions (Tal El Soltan, Balad and El Genena) are as follows: the buildings are constructed of stone and spostos, and stone and concrete as shown in table (4.3).

Table (4.3) :Radon concentrations versus material of house.

Location	Stone and spostos C(Bq/m³)	Stone and concrete C(Bq/m³)	No. of detectors
Tal El Soltan	94.1 (84.2 – 111.3)	69.8 (55.4 - 76.5)	49
Balad	85.2 (79.8 – 124.7)	56.3 (48 – 68.4)	44
El Genena	83.7 (77.1 – 102.4)	72.8 (52.5 – 80.4)	45
No. Of Det.	38	100	Sum(138)
Ave. value	87.7	66.3	----

The table (4.3) indicates that Radon concentration of the houses built of spostos and stone were 1.3 times higher than of houses built of concrete and stone in all regions .

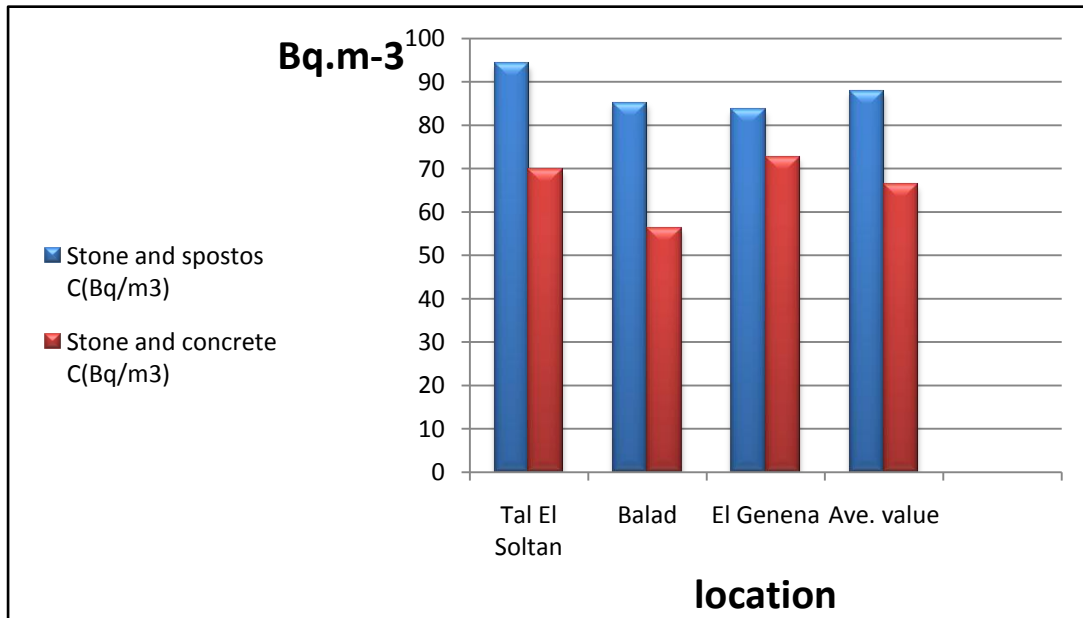


Figure (4.4):Radon concentration variation with materials of building of houses.

Figure (4.4) indicates that the higher Radon concentrations were in the houses built of stone and spostos in the three regions in comparison with the houses built of stone and concrete. Houses built of stone and concrete had low Radon concentrations in all house locations. The ventilation method in these buildings can be understood to be better than other buildings. The concentrations of Radon inside a house are varying in accordance

with constructional characteristics of their foundations and by the type of ventilation system in use. Since the building materials used in the construction of detached houses are different of Radon concentration. This indicates that the different materials of houses are important parameters in determining Radon concentrations.

4.5 The variation of Radon concentrations in different rooms in the house

These results for work places (rooms) show that Radon concentrations vary from a room to another room. Although the Radon source is often concentrated in one room or in one part of the buildings, the gas streams into the other parts of the buildings, mainly because of the ventilation rate. Table (4.4) shows the Radon concentrations versus the different part (bedroom, living room and kitchen) of different buildings.

Table (4.4): Radon concentrations versus different rooms

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

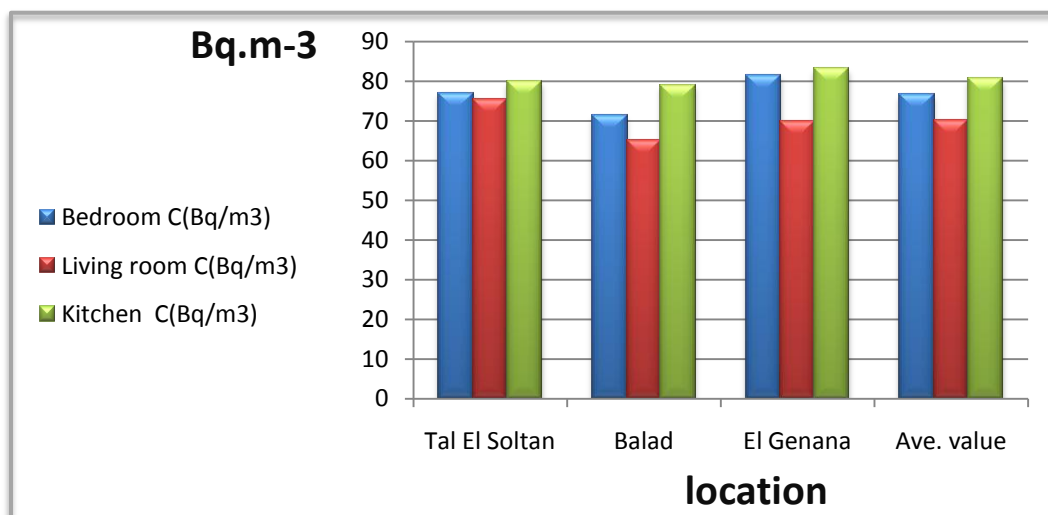
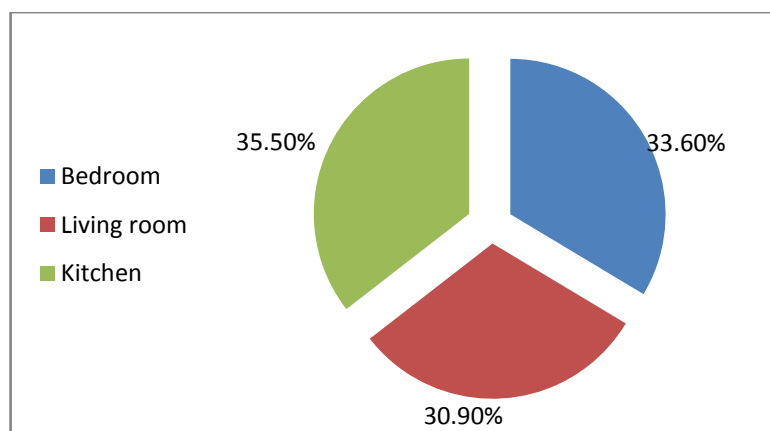


Figure (4.5): Radon concentrations in different rooms of the houses .

Figure (4.5) indicates that the highest Radon concentration was found in the bedroom and kitchen in most regions. While the living rooms have low Radon concentrations

in most regions, and also shows Radon concentrations depending on ventilation more than on the location. This was clear from questionnaire throughout survey of the present work.

Figure (4.6) indicates that the variation of Radon concentration percentage according to different rooms in the region of study of Rafah houses as following: (kitchen 35.5%, living room 30.9% and bedroom 33.6%). On the other hand, the kitchen in this section has the highest Radon level. Where the living room has lowest Radon levels. The kitchen has poor ventilation; because it has small window this may be the reason that raises this radon level in kitchen, also the common use of ceramic and granite in the kitchen may be an important reason to increase Radon concentration.



Figure(4.6) :Percentage of Radon concentrations in different rooms of the house.

One of the most important results of the previous analysis and evolutions was confirmed that Radon concentration values correlate very well with the different rooms.

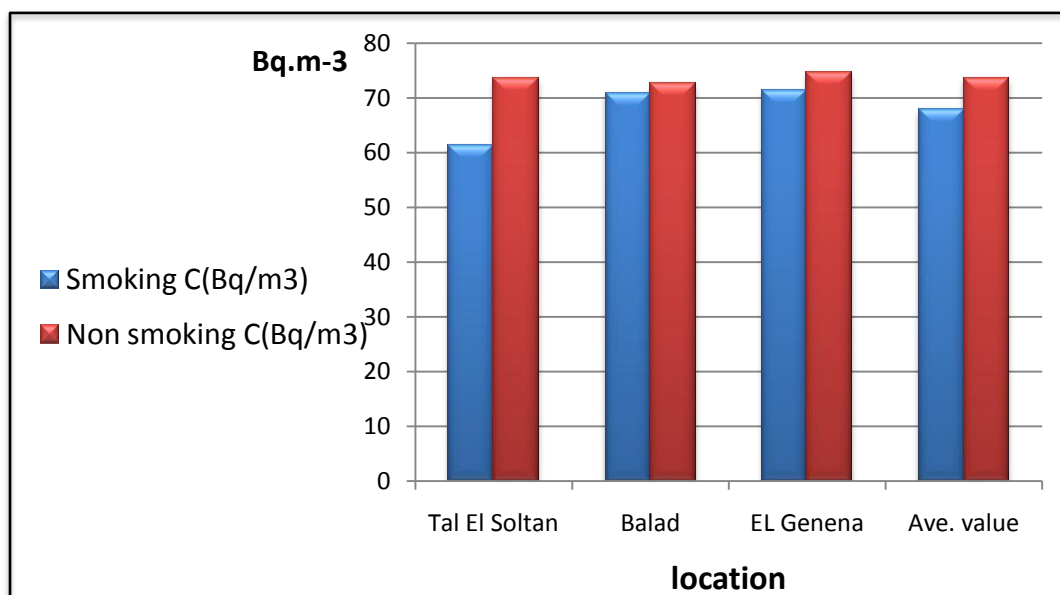
4.6 Smoking effect

It is necessary to focus on an important environmental problem, which is smoking. The risk of smoking, as everyone knows, is duration dependent and cumulative. Exposure to Radon and cigarettes smoking may combine to increase the risk of lung cancer. Research has compared the cancer rate in smoking and non-smoking uranium miners. Results indicate that smoking increases earlier development of lung cancers that may have been caused by the Radon (EPA,2003). In addition, there is an interactive effect between the Radon exposure and cigarettes smoking. Two agents are really causing and developing of lung cancer. The risk of lung cancer caused by smoking is much higher than caused by indoor Radon (Durrani and Radomir,1997).

Table (4.5): Smoking effect of the house

Location	Smoking C(Bq/m ³)	Non smoking C(Bq/m ³)
Tal El Soltan	61.3	73.7
Balad	70.9	72.7
EL Genena	71.3	74.6
No. Of Det	22	125
Ave. value	67.8	73.6

Table (4.5) exhibits that the variation of the average Radon concentration according to smoking status (non-smoking 73.6Bq/m³ and smoking 67.8Bq/m³).



Figure(4.7): Smoking effect of the houses.

Figure (4.7) shows that Radon concentration of the houses have non smoking people is higher compared with the houses have smoking people. Smokers should keep their exposure to Radon as low as possible.

4.7 The age of the building effect

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

Table (4.6): The age effect of the house

Location	Age of building (0-10)year C(Bq/m³)	Age of building (10-20)year C(Bq/m³)	Age of building (20-30)year C(Bq/m³)	Age of building (30-40)year C(Bq/m³)
Tal El Soltan	73	69.2	83.7	89.5
Balad	65	72.1	75	91.5
El Genena	56.9	75.5	86.3	83.7
No. Of Det	33	66	39	12
Ave. value	64.9	72.3	81.6	88.2

We have seen the slight age dependency as shown in table (4.6). The old buildings have higher radon concentration than the newest buildings, this result equivalent to the result found by Sersawy(2007) who found radon concentration in old buildings are higher than in new buildings. This depends on the building material construction in new building. In additional, the old building mostly have cracks and holes due to old age and current wars that could let the Radon animates easily from those holes to the houses However, in our region of study the difference may be due to the style of life, and high ventilation rate as well as to permanent air exchange.

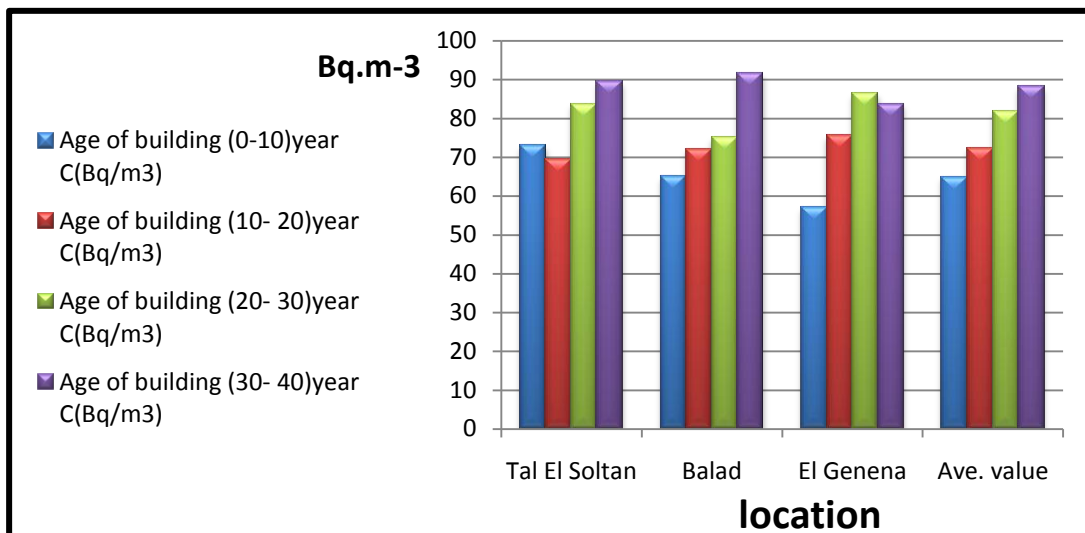


Figure (4.8): The age effect of the house on Radon concentration.

4.8 The ventilation rate

The important factors affect the Radon concentration are the ventilation rate and air exchange. In this chapter no section haven't the ventilation as the reason of high or low Radon concentration. Therefore, we have divided the houses of study to three types of houses: bad ventilation, intermediate ventilation and good ventilation. Bad ventilation has small windows or windows left opened less than three hour a day, intermediate ventilation has left windows for three to eight hour daily and good ventilation has left windows opened more than eight hour a day. This has been observed from the questionnaire. From the results (table (4.7)) obtained from the area of study; It is found that Radon concentration is dependent of ventilation rate. That is in bad ventilation houses have the highest radon level is obtained and the lowest radon level in good ventilation. Thus the relation is inverse between radon level and ventilation rate. Table (4.7) also shows variation of radon concentrations with ventilation rate for different regions.

Table (4.7): Radon concentrations versus with ventilation rate.

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

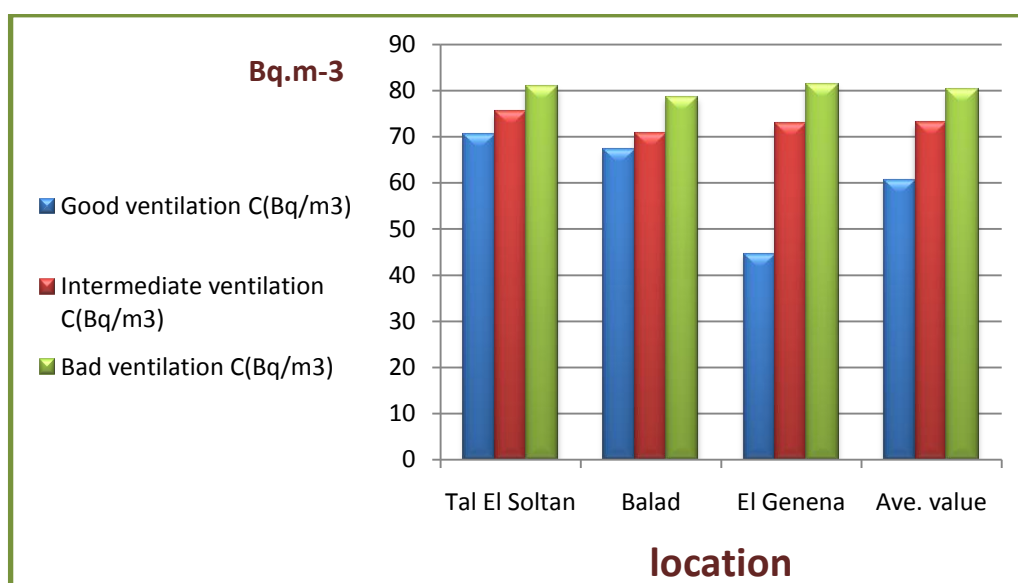


Figure (4.9): Radon concentrations versus with ventilation rate.

Figure (4.9) describes the histograms of Radon concentrations for various rates of ventilation in the buildings locations. It can be seen that Radon levels inside the bad ventilation are much higher than the Radon levels in the intermediate and good ventilation.

Figure (4.10) shows that the variation of Radon concentration percentage according to ventilation rate in the region of study of Rafah buildings as follows: (Good ventilation 28.4%, Intermediate ventilation 34% and Bad ventilation 37.5%). On the other hand, the Bad ventilation all over our current study has the higher Radon level and this due to less exchange of the air through the hous.

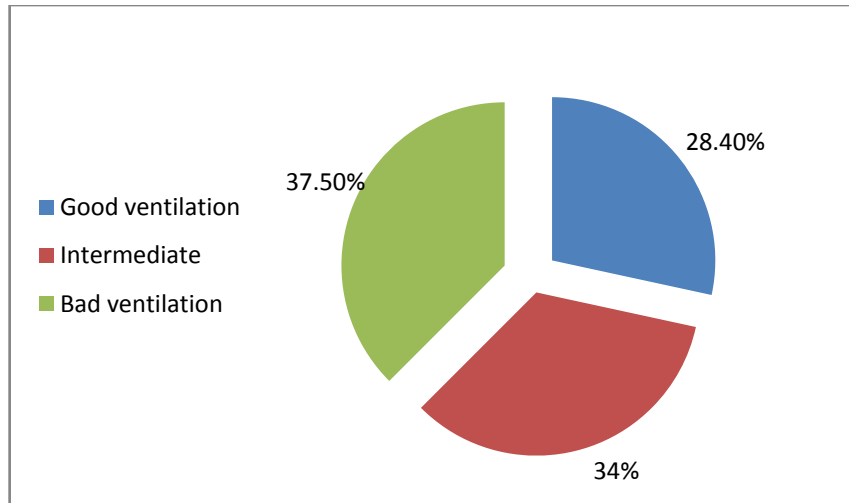
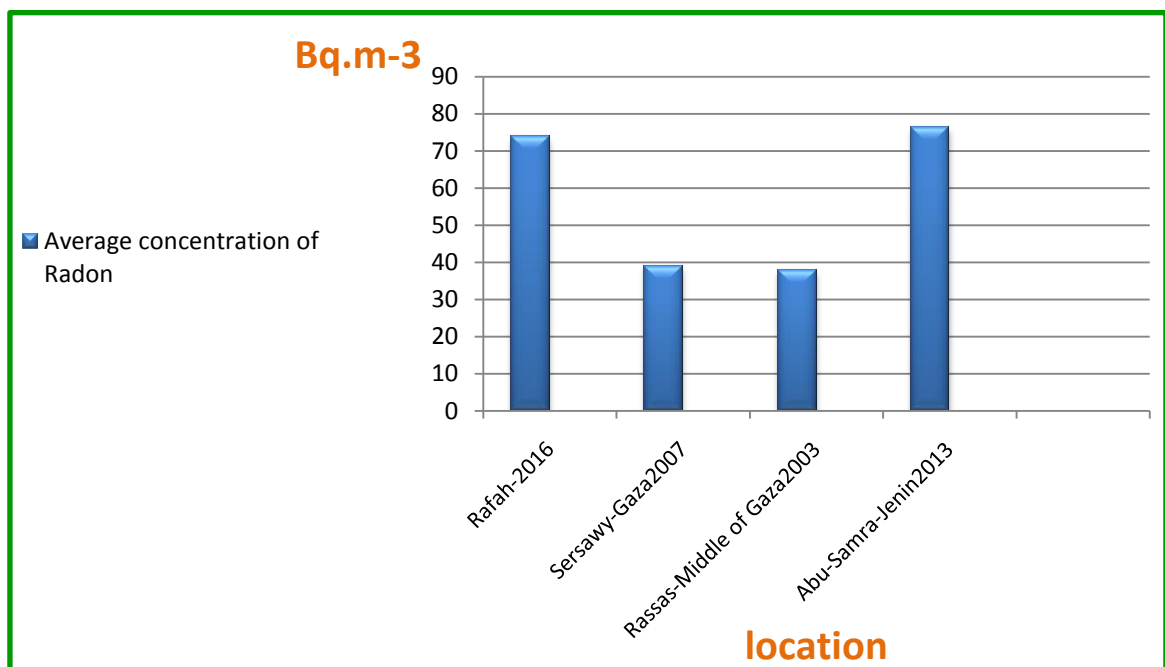


Figure (4.10): Percentage of Radon concentrations versus with ventilation rate.

Comparison with previous studies

We have compared our result with the previous studies that carried out the radon measurement in different areas of Gaza Strip and West Bank. The results indicate that radon concentration in Rafah city have higher values of the other regions in Gaza Strip and close to that of Jenin as shown in the figure(4.11). This may be attributed to Rafah city has a different Geography ,Tomography(see section 2.1), as well as this region subjected to many wars and attacks with the enemy with different types of weapons.



Figure(4.11): Comparison with previous studies of Radon concentration

Chapter 5

Conclusions and Recommendations

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

The inhalation of Radon and its short-lived daughter products represents the main source of exposure to natural radiation. Radon is now believed to be the most important source of ionizing radiation in our environment. Radon is a gas that is produced naturally in the ground and seeps into most houses. The study purpose was to find out an approximate mean and range of Radon in the houses in order to estimate the possible health hazards from Radon in Rafah city. The current study is planned to determine the extent and severity of Radon problems in the locations of Rafah city. The plastic cup containing (solid state nuclear track detectors CR-39), are used for indoor radon monitoring. The detectors are cut in small pieces (usually 1cm x 1cm) and fixed at the bottom of the plastic cup. The indoor radon levels have been estimated in about 50 houses (three locations) in Rafah city using integrating etched track detector. The three regions were investigated and the radon level determined. The devices are exposed to Radon for a time period of three months, after which they were collected and the CR-39 films were chemically etched using a 6M solution of NaOH, at a temperature of 70⁰C, for about 5 hours. The detectors were then washed thoroughly with distilled water and left to dry. Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 4 distinct regions were observed; through the area (1mm²) see figure (4.1), the average number of tracks/mm² was determined and analyzed. Surveys have been conducted in different types of houses in the region of study (Rafah city), houses built of different material like (stone and spostos) and (stone and concrete) which we know the Radon concentration depends, also Radon concentration depends on the height of the buildings and ventilation rate. These dosimeters were randomly distributed in a bedroom, in a living room or in kitchen.

Generally, the result was found 73.6Bq/m³ (1.99 pCi/l) with a range of values between 16.5 and 150.4 Bq/m³ (0.44 and 4.06 pCi/l) and a maximum value of 180.7Bq/m³ (4.8 pCi/l) with average standard deviation of 15. 1,the result in Rafah city is lower than the concentration action level(148 Bq/m³) which made by Environmental Protection Agency (EPA) and International Commission on Radiological Protection (ICRP). Despite

of the limited number of detectors used in this survey, the obtained results indicate a variability in radon concentration that expected in building of Rafah city, It is found that the ventilation is the key factor that affects the radon concentration, particularly in low level rise of building rather than the higher buildings. We cannot neglect the big effect of the houses material on the radon concentration and the effect of the age of the building on the variation of the radon concentration level.

This would give a wider frame work for natural radiation measurement in Gaza strip that provide data specially from environmental point of view.

It is also evident that each house has its own level of Radon concentration. Therefore, it is not possible to generalize and say that it is enough to measure the Radon level in one house and believe that neighboring houses have the same Radon level.

Despite all the work that has been accomplished to the present, it well to keep in mind that strategies for controlling the indoor entry of Radon rate still in research stage and some techniques indicated as useful in the past have since been shown to be ineffective.

Generally speaking, poor ventilation is the main reason for having higher radon concentration levels in closed places. Improving ventilation of these places will increase air exchange rates with the outside, thereby resulting in reducing radon concentration levels. Accordingly, remedial efforts should be focused mainly on reducing the radon concentration levels as well as effective consideration to improve the ventilation and adopt the mitigation technique to reduce the concentration of radon from the buildings. Although the study is limited, the results provide a framework for future studies that include a larger, broader survey of Radon concentrations indoor in Rafah.

In conclusion, the measured radon concentration levels was found to be less than the reference levels set by various radiation protection agencies. Accordingly, radon cannot be considered as a major radiological risk for inhabitants at Rafah city.

In fact, we would like to pay the attention of the readers to many obstacles encountered this research.

First: the great preoccupation with security imposed by the general situation in which we live in the Gaza Strip as a result of the Israeli blockade and continued wars on Gaza Strip. There was great difficulty in reassuring people by the safety and security of this type of investigating of radon. Particularly, since the examination requires that the presence of chips inside the rooms for a long period of almost 90 days then should be collected and re-examined.

Second: Accordingly, due to the above mentioned reasons ,this makes people to be doubt and very concern. This increases the time and efforts of the distribution process ,where people ask many questions of this work.

Third: the distribution of the chips inside rooms, including the bedroom raised the doubt of many people as a result the home looked into it, taking into account individual differences in culture of people .Certainly, the fear of the presence of those detectors made me very embarrassed and compelled me to further explain the aim of the research to reassure people.

Fourth: the distribution of examination detectors inside the private rooms in houses were done by the owner of the house himself where it could not be able to continue installing of the detectors to put them fully healthy situation on the appropriate altitude. However, we recommend them the best conditions for the proper installation of the detectors inside the rooms to get the best results.

Furthermore, the biggest challenge in this work was to obtain the samples of detectors(CR39) which not available in the Gaza Strip because of the blockade. However we have worked very hard to obtain the detectors. This is due to the help of God and loyal efforts of some people this work achieved.

5.2 Recommendations

The measurement of indoor Radon levels is an important factor in the evaluation of impacts on public health. Radon concentrations in indoor air may increase in the future, as a result of the utilization of new building materials, the implementation of energy conserving measures, and the change in living condition. These factors may thus lead in the future to an increase in the levels of indoor radiation exposure to the population. Without testing, it is impossible to tell which particular houses in a given area that may have high Radon levels. Radon levels vary widely not only from area to area, but even from house to house.

Substantial research efforts are also required to the other parts of Gaza strip to estimate the average Radon concentration of the whole country. These primary results also provide a basis for an extensive survey programs covering major cities and locations of high interest.

Efforts to control Radon concentrations in houses may be achieved by a number of ways directed towards reducing Radon entry, including:

1) Removing Radon source

Removing contaminated soil and building materials, since it was known that the cinderblock walls are usually more porous than ordinary concrete or stone. In these cases, the entire source can be isolated (Shoqwara,2012).

2) Preventing Radon entry to the house

Fixing the openings in the house basement by elimination of cracks in the walls and other entry channels in the basement. Ventilating the soil to divert soil gas away from the house. Adjusting the pressures inside the house to reduce or eliminate the driving force for soil gas entry. Treating the well water entering the house.

3) Removing Radon from the house including:

I) House ventilation, increased ventilation of the house with use of air-to-air heat exchangers or by opening windows on two or more sides of lower level of the house (and on upper levels if these are the primary living areas).

II) Air cleaning techniques, Radon can be removed from the environment by a filtration device made up of fans used to direct air through a mechanical filter.

It is apparent that if the Radon is removed the progeny will not exist in the indoor air. Consequently, removing the Radon is sufficient to remove the health risk associated with Radon progeny. Since Radon concentration tend to be greater on the lower levels of a house. Spending the most times in the living rooms and ventilation the bedrooms “that location is in the upper floor”.

We recommend that the effect of the type of the floor(such as ceramic, concrete ,clay.....etc) on the concentration of Radon in the houses should be taken into account. Scientific evidence indicates that smoking may increase the risk of exposure to Radon. Stopping smoking and discouraging smoking in your home should reduce the risk that you or member of your family will develop lung cancer from inhalation of Radon.

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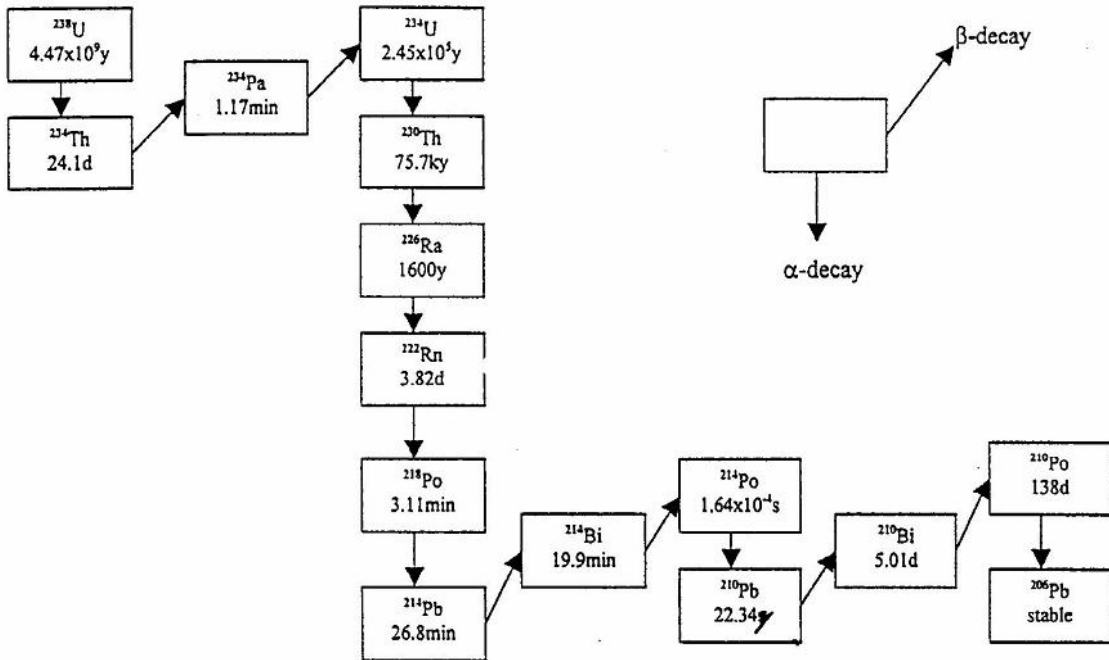
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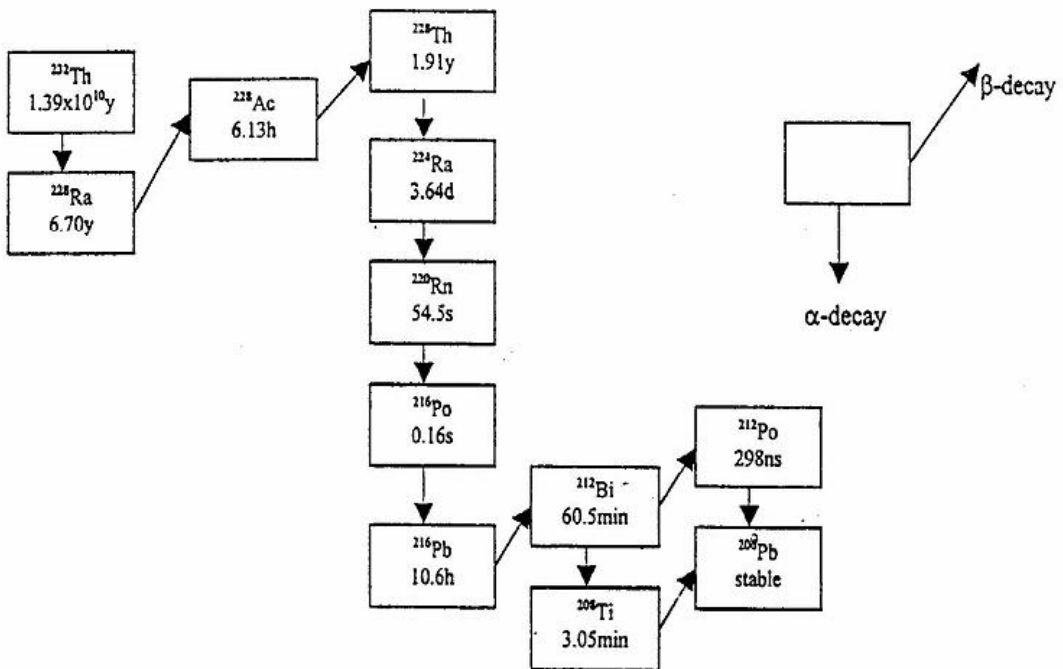
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Appendix 1



The decay series of U^{238}



The decay series of Th^{232}

Appendix 2 Questionnaire

The name:..... detector No:.....

Location Tal El Soltan: , Balad(Rafah camp): , El Genena: .

Type of location: **House:** Bedroom: , living room: , kitchen: .

Shop: , Pharmacy: , super market , others:

• **Building construction:** stone and concrete: , stone and spetose:

Zinc: , others: .

• **Air conditioner in location** yes, no.

• **Established date of building constructed:.....**

• **Primary source of water:** domestic water ground water wells

• **The level of the house**

• Basement: , 1st floor: , 2nd floor: , 3rd floor: , 4th floor: ,

5th floor: , Others:.....

• **The type of heating fuel used in the house:** natural gas:, wood:,
electricity : ,

• **The time you spent in house:.....**

• **Ventilation rate:** good: , middle: , bad: .

• **For man**

- **Job:.....**

- **Do you smoke?** Yes: , no: .

- **Does any person suffer from any diseases concerning cancer.....**

- **Information of detector**

• **Beginning date.....**

• **Collective date.....**

• **Average no. of track/cm².....**

• **Concentration of radon Bq/m³**

Comments:.....

.....

