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Radon Exhalation Rate From Destroyed Building Materials in Gaza, Palestine.

BY

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Thesis

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نموذج رقم (١)

إقـــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Radon Exhalation Rate From Destroyed Building Materials in Gaza, Palestine.

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The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification

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نتيجة الحكم على أطروحة ماجستير

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قياس معدل انبعاث غاز الرادون من مواد البناء المدمرة غزة– فلسطين

Radon Exaulation Rate From Destroyed Building Materials In Gaza, Palestine

وبعد المناقشة العلنية التي تمت اليوم الثلاثاء 26 رجب 1437هـ، الموافق 2016/05/03م الساعة الواحدة ظهراً بمبنى القدس، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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

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(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ ۚ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

صدق الله العظيم

سورة المجادلة آية (11)

(عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَم)

صدق الله العظيم

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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. This study aims at assessing the contribution of destroyed building materials in war 2014 towards the total indoor radon exposure to the inhabitants of Jabalia district in Gaza. 40 Samples have been collected from common destroyed building materials in 2014 war in Jabalia district. The closed-can technique has been employed in this study using solid state nuclear track detectors (CR-39). After 124 days of exposure to radon, CR-39 detectors were etched chemically by (6N) NaOH solution at 75C for 4.20 hours and then counted under an optical microscope. The measured track densities were related to radon concentrations, radon exhalation rate in term of area E_x, radon exhalation rate in term of mass E_m and the annual effective dose for forty building material samples. Results obtained from the current study show that radon exhalation rates from concrete and asbestos have relatively high values as compared to other building material while glass, marble and a red brick contribute less to radon exhalation rate. The average radon exhalation rate in term of area in the studied samples ranged from (86.506) $mBq.m^{-2}.h^{-1}$ for glass samples to (469.017) $mBq.m^{-2}.h^{-1}$ for Concrete samples, with a total average value of (219.815) $mBq.m^{-2}.h^{-1}$, the corresponding total average value of radon concentration and radon exhalation rate in term of mass are (175.95) Bq/m^3 and (5.550) $mBq.Kg^{-1}.h^{-1}$, respectively. On the basis of these values the annual effective dose for each sample was also determined and compared with the effective dose limit values recommended by the National Council on Radiation Protection and Measurements (from 1 to 5 mSv/y). In general, the annual effective doses from the investigated building materials are low and under the global value except for Concrete and asbestos samples with average values(9.464) and (9.3528) mSv/y, respectively. Thus the studied materials are safe as construction materials especially with good ventilation rate, but special care must be taken when using Concrete and asbestos as building materials. In comparison with values we measured with other people values, we see that we are very close in numbers, the differences are due to the different in origin of building materials, and the different in calibration numbers from place to other place. Also we compare the destroyed building materials with the fresh one, we see also not a big difference, which mean there is no pollution from the war or we may need more accurate devices to detect radio nuclei like Uranium. .

Chapter (1)

Introduction

1.1.Study Objectives

The purpose of this study is to measure the Radon exhalation rates from destroyed building materials during 2014 war against Gaza, Palestine. Our study will include samples of a red brick , marble, ceramic, concrete, tiles, asbestos, glass and building stones from different origins used in the mentioned area of study.

1.2. study Problem

All building materials contain various amounts of main natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and since those radionuclides are sources of Radon gas then the knowledge of the natural radioactivity of building materials is important for the determination of population exposure to radiations. For the aforementioned reasons we intend to study the concentration of Radon and the exhalation rate from destroyed building materials in the 2014 war used in the districts of Jabalia in the northern Gaza Strip. It will then be compared to results obtained with the results of previous studies. Then I will study the health risks of radon gas.

1.3. Introducing the area of study

In this study, we present our data concerning measurement of the radon exhalation rate from destroyed building material samples collected from Jabalia district in the Gaza strip in Palestine using close vessel technique. The location of this district is shown in Figure 1.1. Houses in this district are mainly constructed from soil, bricks, cement, sand, granite and marble. This district is located in the northern part of the Gaza strip of Palestine [1].

1.3.1. Geography

Jabalia is a Palestinian city located 4 kilometers (2.5 mi) north of Gaza city. It is under the jurisdiction of the North Gaza Governorate, in the Gaza strip. Jabalia had a population of 82,877 in mid-2006. The nearby town of Nazla is a part of the Jabalia municipality [1].

1.3.2. Climate

The relatively temperate Mediterranean climate brings hot, dry summers and cool, rainy winters to Jabalia. Spring arrives around March– April and the hottest months in Jabalia are July and August with the average high being 29.4 °C. The coldest month is January with temperatures usually at 7.2 °C. Rain generally falls between October and March [2].

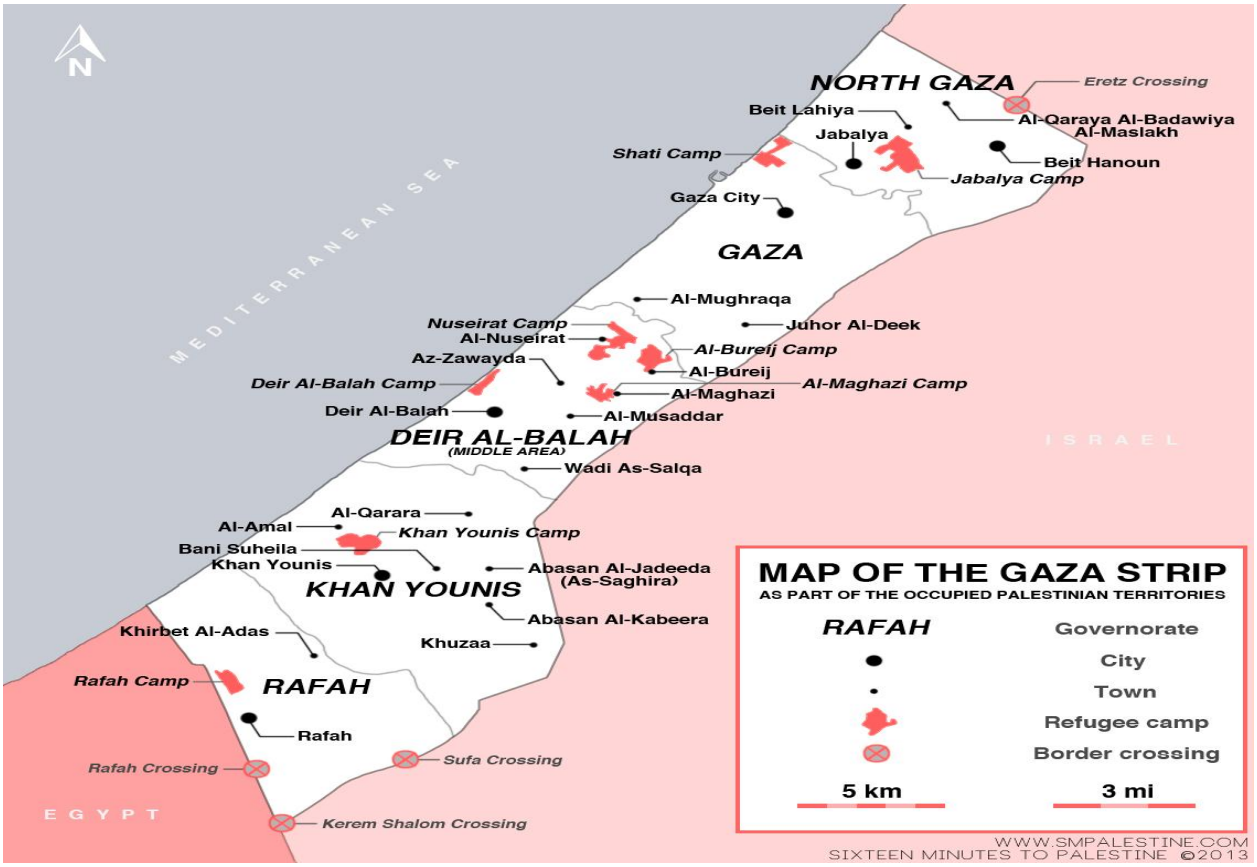

Figure 1.1 Gaza strip

1.4.Previous Studies

In a neighboring country, Egypt, a study on ^{222}Rn exhalation rate from Egyptian building materials was performed in 2009 and found that the radon exhalation rate in the studied samples ranged from (2.2 x 104 ± 7.2 x102) μBq m^{-2} s^{-1} , for granite sample, to (3.4x101 ± 9.0x100) μBqm^{-2} s^{-1}, for portland cement with an average value (1.8x103 ± 6.5x101) μBq m^{-2} s^{-1} [3]. El-Ghossain et. al. , the activity of alpha, beta and gamma radiation, in tap water in the north-east of Gaza (Al-Naser area) were measured. For this purpose we used a solid state nuclear track detectors (CR-39) and some other detectors (Geiger counter, NaI detector). The average gross alpha concentration from C4-39 is 35.50 Bq/m3 (0.95 pci/L), the maximum concentration is64.67 Bq/m3, and minimum concentration is 24.20 Bq/m3 [4]. The radon concentration in Air at middle of Gaza Strip was measured, the average radon concentration 37.83 Bq/m^3 [4]. In Gaza, Palestine , the radon concentration in soil in at north of Gaza Strip, was measured by N. M. Hammed (2005). The results of the average radon concentration was 207.24 Bq/m^3 [5] . M. Rasas (2003) measured the radon concentration in Air at middle of Gaza Strip, the average radon

concentration in Air was 37.83 Bq/m^3 [6]. Then radon concentration values have been measured using passive integrated solid-state nuclear track devices. Results show that the minimum average value of radon concentration found in the main channel water samples to be (6.93±1.68)Bq/L, while the maximum average value measured in Sagia (2) water samples to be (22.74±4.89) Bq/L. From our study, we found that there are no any remarkable variations seen in radon concentration for water samples taken from Hafeirs and Rivers. The overall average radon concentration for all water samples is found to be (14.24 ±3.62) Bq/L[7].In Nablus district, Palestine , The measured Radon exhalation rates from granite and marble have relatively high values as compared to other building materials followed- in order- by cement, ceramic, concrete, building stones, and porcelain, while gypsum, sand, gravel and bricks contribute less to radon exhalation rate which was found to range from (55.37 ± 15.01) mBq/m^2h for gypsum samples to (589.54 ± 73.24) mBq/m^2h for granite samples, with a total average value of (268.56 ± 166.21) mBq/m^2h. The corresponding radon concentration, effective radium content, and annual effective dose average values were (148.49 ± 91.13) Bq/m^3, (1.93 ± 1.20) Bq/Kg and (3.74 ± 2.30) mSv/y [8].

1.5.Radiation

Radiation is energy. It can come from unstable atoms or it can be produced by machines. Radiation travels from its source in the form of energy waves or energized particles. There are actually two kinds of radiation, and one is more energetic than the other. It has so much energy it can knock electrons out of atoms, a process known as ionization. In the late 1800s, Marie and Pierre Curie were among the first to study certain elements that gave. off radiation. They described these elements as radio-active, the property that is now called “radioactivity.” As scientists studied radioactivity more closely, they discovered that radioactive atoms are naturally unstable. In order to become stable, radioactive atoms emit particles and/or energy waves. This process came to be known as radioactive decay. The major types of ionizing radiation emitted during radioactive decay are alpha particles, beta particles and gamma rays. Other types, such as x-rays, can occur naturally or be machine-produced. Scientists have also learned that radiation sources are naturally all around us. Radiation can come from as far away as outer space and from as near as the ground that you are standing on. Because it is naturally all around us, we cannot eliminate radiation from our environment. We can, however, reduce our health risks by controlling our exposure to it [9].

1.6. Atoms: Where all matter begins

Atoms form the basic building blocks of all matter. In other words, all matter in the world begins with atoms – they are elements like oxygen, hydrogen, and carbon. An atom consists of a nucleus – made up of protons and neutrons that are kept together by nuclear forces – and electrons that are in orbit around the nucleus. The nucleus carries a positive charge; protons are positively charged, and neutrons do not carry a charge. The electrons, which carry a negative charge, move around the nucleus in clouds (or shells). The negative electrons are attracted to the positive nucleus because of the electrical force. This is how the atom stays together. Each element is distinguished by the number of protons in its nucleus. This number, which is unique to each element, is called the "atomic number" Z. In an atom of neutral charge, the atomic number is also equal to the number of electrons. An atom's chemical properties are determined by the number of electrons, which atoms from one or more elements combine to form molecules. A nuclide is a specific type of atom characterized by the number of protons and neutrons in its nucleus ${}_{Z}X^{A}$, which approximates the mass of the nuclide. The number that is sometimes given with the name of the nuclide is called its mass number A (the total number of protons and neutrons in the nucleus) [10] .

1.7. Isotopes

Some isotopes are unstable, and therefore radioactive, while others are stable, and thus non-radioactive. So – what is an isotope? The nucleus of an atom consists of protons and neutrons (called nucleons). The number of protons determines the element and its chemical properties. The number of nucleons determines the atomic weight. "Isotopes are atoms with the same number of protons, but with different numbers of neutrons." Isotopes are chemically equivalent, but have different atomic weights [11] . All elements have several isotopes – some of them may even be unstable and thus radioactive. An attempt to illustrate this is shown below for the most common of the elements, hydrogen which has three isotopes. They all have a nucleus with one proton. However, the number of neutrons are; zero, one and two. Isotopes are written using the symbol for the element, such as H for hydrogen, O for oxygen, and U for uranium. Furthermore, the nucleon number (the sum of protons and neutrons) is used to separate the isotopes [12] .

Isotopes that are not stable and emit radiation are called radioisotopes. A radioisotope is an isotope of an element that undergoes spontaneous decay and emits radiation as it decays. During the decay process, it becomes less radioactive over time, eventually becoming stable. Once an atom reaches a stable configuration, it no longer gives off radiation. For this reason, radioactive

sources – or sources that spontaneously emit energy in the form of ionizing radiation as a result of the decay of an unstable atom – become weaker with time. As more and more of the source's unstable atoms become stable, less radiation is produced and the activity of the material decreases over time to zero. The time it takes for a radioisotope to decay to half of its starting activity is called the radiological half - life, which is denoted by the symbol $t_{½}$.Each radioisotope has a unique half-life, and it can range from a fraction of a second to billions of years. A radioisotope with a short half-life is more radioactive than a radioisotope with along half-life, and therefore will give off more radiation during a given time period. There are three main types of radioactive decay: Alpha decay , Beta decay and Gamma decay. [13]The number of nuclear disintegrations in a radioactive material per unit time is called the activity. The activity is used as a measure of the amount of a radionuclide, and it is measured becquerels (Bq). 1 Bq = 1 disintegration per second. If the original source of the radioactivity is known, it can be predicted how long it will take to decay to a given activity. The decay is exponential and the isotope must go through many half -lives to become non--radioactive according to the radioactive law

$$N=N_0 e^{-\lambda t} \qquad 1.1$$

$$T_{1/2} = 0.693/\lambda \qquad 1.2$$

λ is the decay constant, N number of nuclei at time t, N_0 initial number of nuclei at t=0. Even after a radioisotope with a high activity has decay for several half-lives, the level of remaining radioactivity is not necessarily safe. Measurements of a radioactive material's activity are always needed to estimate potential radiation doses [10] .

1.8. Types and Sources of Radiation

Radiation is energy in the form of waves of particles. There are two forms of radiation – non-ionizing and ionizing radiation:

1.8.1. 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. Global positioning systems, cellular telephones, television stations, FM and AM radio, baby monitors, cordless phones, garage-door openers, and ham radios use non- ionizing radiation. Other forms include the earth's magnetic field, as well as magnetic field exposure from proximity to transmission lines, household wiring and electric appliances. These are defined as extremely low-frequency (ELF) waves and are not considered to pose a health risk [10].

1.8.2. Ionizing radiation

Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials [9]. There are several types of ionizing radiation

a)Alpha radiation (α)

Some unstable atoms emit alpha particles (α). Alpha particles are positively charged and made up of two protons and two neutrons from the atom's nucleus, as shown in the illustration at the right. Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances and are unable to travel very far from the atom. The health effect from exposure to alpha particles depends greatly on how a person is exposed. Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Inside the body, however, they can be very harmful. If alpha-emitters are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue. The way these large, heavy particles cause damage makes them more dangerous than other types of radiation. The ionizations they cause are very close together they can release all their energy in a few cells. This results in more severe damage to cells and DNA [9].

b)Beta radiation (β)

Beta particles (β) are small, fast-moving particles with a negative electrical charge that are emitted from an atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (tritium), carbon-14 and strontium-90. Beta particles are more penetrating than alpha particles but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating the skin and causing damage such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or swallowed [9].

c) Photon radiation (gamma [γ] and X-ray)

Photon radiation is electromagnetic radiation. There are two types of photon radiation of interest for the purpose of this document: gamma (γ) and X-ray. Gamma radiation consists of

photons that originate from within the nucleus, and X-ray radiation consists of photons that originate from outside the nucleus, and are typically lower in energy than gamma radiation. Photon radiation can penetrate very deeply and sometimes can only be reduced in intensity by materials that are quite dense, such as lead or steel. In general, photon radiation can travel much greater distances than alpha or beta radiation, and it can penetrate bodily tissues and organs when the radiation source is outside the body. Photon radiation can also be hazardous if photon-emitting nuclear substances are taken into the body. An example of a nuclear substance that undergoes photon emission is cobalt-60, which decays to nickel-60 [10].

d)Neutron radiation (n)

Apart from cosmic radiation, spontaneous fission is the only natural source of neutrons (n). A common source of neutrons is the nuclear reactor, in which the splitting of a uranium or plutonium nucleus is accompanied by the emission of neutrons. The neutrons emitted from one fission event can strike the nucleus of an adjacent atom and cause another fission event, inducing a chain reaction. The production of nuclear power is based upon this principle. All other sources of neutrons depend on reactions where a nucleus is bombarded with a certain type of radiation (such as photon radiation or alpha radiation), and where the resulting effect on the nucleus is the emission of a neutron. Neutrons are able to penetrate tissues and organs of the human body when the radiation source is outside the body. Neutrons can also be hazardous if neutron-emitting nuclear substances are deposited inside the body. Neutron radiation is best shielded or absorbed by materials that contain hydrogen atoms, such as paraffin wax and plastics. This is because neutrons and hydrogen atoms have similar atomic weights and readily undergo collisions between each other. Figure (1.2) summarizes the types of radiation discussed in this document, from higher- energy ionizing radiation to lower -energy non-ionizing radiation. Each radiation source differs in its ability to penetrate various materials, such as paper, skin, lead and water [10].

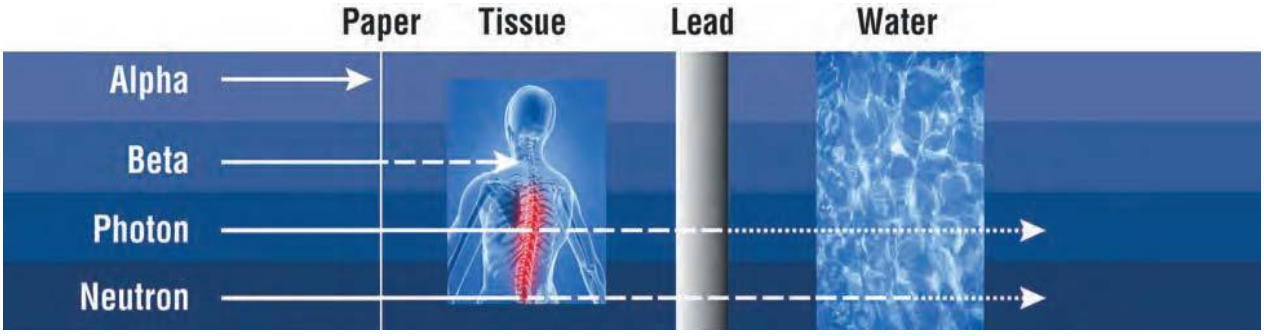

Figure 1.2: Penetration abilities of different types of ionizing radiation

1.8.3. Natural Sources of Ionizing Radiation

Radiation has always been present and is all around us in many forms. Life has evolved in a world with significant levels of ionizing radiation, and our bodies have adapted to it. Many radioisotopes are naturally occurring, and originated during the formation of the solar system and through the interaction of cosmic rays with molecules in the atmosphere. Tritium is an example of a radioisotope formed by cosmic rays' interaction with atmospheric molecules. Some radioisotopes (such as uranium and thorium) that were formed when our solar system was created have half-lives of billions of years, and are still present in our environment. Background radiation is the ionizing radiation constantly present in the natural environment. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) identifies four major sources of public exposure to natural radiation: Cosmic radiation, Terrestrial radiation, Inhalation and Ingestion [14].

a)Exposure from cosmic radiation

The earth's outer atmosphere is continually bombarded by cosmic radiation. Usually, cosmic radiation consists of fast moving particles that exist in space and originate from a variety of sources, including the sun and other celestial events in the universe. Cosmic rays are mostly protons but can be other particles or wave energy. Some ionizing radiation will penetrate the earth's atmosphere and become absorbed by humans which results in natural radiation exposure [15].

b)Exposure from terrestrial radiation

The composition of the earth's crust is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium and thorium which, in the process of natural decay, will release small amounts of ionizing radiation. Uranium and thorium are found essentially everywhere. Traces of these minerals are also found in building materials so exposure to natural radiation can occur from indoors as well as outdoors [10] .

c)Exposure through inhalation

Most of the variation in exposure to natural radiation results from inhalation of radioactive gases that are produced by radioactive minerals found in soil and bedrock. Radon is an odorless and colorless radioactive gas that is produced by the decay of uranium. Thoron is a radioactive gas produced by the decay of thorium. Radon and thoron levels vary considerably by location depending on the composition of soil and bedrock. Once released into the air, these gases will normally dilute to harmless levels in the atmosphere but sometimes they become trapped and

accumulate inside buildings and are inhaled by occupants. Radon gas poses a health risk not only to uranium miners, but also to homeowners if it is left to collect in the home. On average, it is the largest source of natural radiation exposure [16].

d)Exposure through ingestion

Trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation. Naturally occurring radioactive isotopes, such as potassium-40 and carbon-14, have the same chemical and biological properties as their non-radioactive isotopes. These radioactive and non-radioactive elements are used in building and maintaining our bodies Natural radioisotopes continually expose us to radiation and are commonly found in many foods, such as Brazil nuts [10].

1.8.4.Artificial (man-made) sources of ionizing radiation

People are also exposed to man-made radiation from medical treatments and activities involving radioactive material. Radioisotopes are produced as a by-product of the operation of nuclear reactors, and by radioisotope generators like cyclotrons. Many man-made radioisotopes are used in the fields of nuclear medicine, biochemistry, the manufacturing industry and agriculture. The following are the most common sources [17].

a) Medical sources

Radiation has many uses in medicine. The best-known application is in X-ray machines, which use radiation to find broken bones or to diagnose diseases. X-ray machines are regulated by Health Canada and provincial authorities. Another example is nuclear medicine, which uses radioactive isotopes to diagnose and treat diseases such as cancer. A gamma camera is one piece of medical equipment commonly used in diagnosis [17] .

b)Industrial sources

Radiation has various industrial uses, which range from nuclear gauges used in the building of roads to density gauges that measure the flow of material through pipes in factories. Radioactive materials are also used in smoke detectors and some glow-in-the dark exit signs, as well as to estimate reserves in oil fields. Other applications include sterilization, which is performed using large, heavily shielded irradiators [17] .

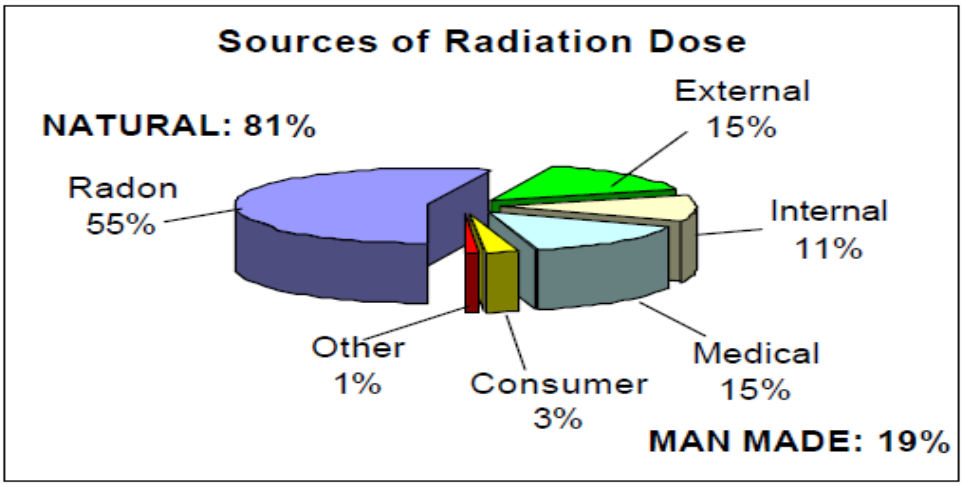

Figure1.3: Sources of Radiation Dose

c) Nuclear Fuel Cycle

Nuclear power plants (NPPs) use uranium to produce a chain reaction that produces steam, which in turn drives turbines to produce electricity. As part of their normal activities, NPPs release small quantities of radioactive material in a controlled manner to the surrounding environment. These releases are regulated to ensure doses to the public are well below regulatory limits. Uranium mines fuel fabrication plants and radioactive waste facilities are also licensed so the radioactivity they release (that can contribute to public dose) [17].

d)Nuclear Testing

The atmospheric testing of atomic weapons from the end of the Second World War until as late as 1980 released radioactive material, called fallout, into the air. As the fallout settled to the ground, it was incorporated into the environment. Much of the fallout had short half-lives and no longer exists, but some continues to decay. People and the environment receive smaller and smaller doses from the fallout every year [17] .

f)Striking a balance

Normally, there is little we can do to change or reduce ionizing radiation that comes from natural sources like the sun, soil or rocks. This kind of exposure, while never entirely free of risk, is generally quite low. However, in some cases, natural sources of radioactivity – such as radon gas in the home – may be unacceptably high and need to be reduced. The ionizing radiation that comes from man-made sources and activities is controlled more carefully. In these settings, a balance is struck between radiation's societal benefits and the risks it poses to people, health and the environment. Dose limits are set to restrict radiation exposures to both workers and members of the public. In addition, licensees are required to keep all radiation doses as low as reasonably

achievable (ALARA). There must also be a net benefit to support the use of radiation. For example, smoke detectors are permitted to use radioactive isotopes because smoke detectors save lives. Similarly, nuclear power plants provide us with electricity, while posing minimal risks that are carefully controlled [17] .

1.9. Health Effects of Radiation Exposure

The word "safe" means different things to different people. For many, the idea of being safe is the absence of risk or harm. However, the reality is that almost everything we do presents a certain level of risk. For example, speed limits on roads are set to maximize safety. Nevertheless, accidents occur even when drivers obey the speed limit. Despite this risk, we still drive. Similar informed decisions are made when radiation is used. Radiation exposure carries a health risk. One significant advantage of radiation is that more is known about its associated health risks than about any other chemical or otherwise toxic agent. Since the early 20th century, radiation effects have been studied in depth, in both the laboratory and among human populations [18, 19].

1.9.1. Epidemiological evidence

Studies on survivors of the atomic bombings of the cities of Hiroshima and Nagasaki in 1945 indicate that the principal long-term effect of radiation exposure is an increase in the frequency of cancer and leukemia. Similar results have been found in these groups:

- people who have been exposed to radiation through medical treatments or diagnostic procedures
- early uranium mine workers
- workers who manufactured atomic weapons
- people exposed to radiation as a result of the Chernobyl nuclear accident
- people exposed to radon gas in their homes

Studies have shown that radiation will increase the frequency of some cancers that already occur naturally (or spontaneously), and that this increase is proportionate to the radiation dose; that is, the greater the dose, the greater the risk of cancer. These are referred to as stochastic effects. However, studies to date have not shown that people chronically exposed to radiation at doses lower than about 100 millisieverts (mSv) per year will experience an increase in cancer or other diseases. The following hypotheses attempt to explain why we cannot see radiation effects at doses of less than 100 mSv per year:

- One possible explanation is a dose threshold below which no cancers are caused; for example, radium has a threshold of 10 Sv for bone cancer.
- Another hypothesis is that the incidence of cancer caused by low radiation doses is so low

that it cannot be distinguished from natural (or spontaneous) occurrences of the same cancer.

Scientists continue to try to detect the effects of low-dose radiation to support either of these potential explanations. Most people who showed health effects in studies were exposed to relatively high doses (greater than 100 mSv) delivered over a very short period of time. This is known as "acute" exposure. Normally, workers and members of the public exposed to radiation from the nuclear industry receive much lower doses over a considerably longer period of time (years as opposed to seconds). This is known as "chronic" exposure. Acute radiation exposure is estimated to be about1.5 to 2 times more likely to produce health effects than chronic exposure. [18, 19].

1.9.2. Cancer Risk Assessment

The International Commission on Radiological Protection (ICRP) has calculated the probability of fatal cancer by relying primarily on the assessment of radiation effects by scientific bodies such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the Biological Effects of Ionizing Radiation (BEIR). It then determined what it calls the overall "detriment" of radiation exposure. This includes [20] :

- the probability of fatal cancer
- the probability of non-fatal cancer
- the probability of severe hereditary effects
- the length of life lost if the harm occurs [20].

Using all these risks, the ICRP calculated an overall detriment of 0.042 (4.2%) per sievert for adult workers and 0.057 (5.7%) per sievert for the overall population (ICRP 103). The risk for the overall population is slightly higher than that of workers due to differences in certain variables, such as sex and age ranges, that were taken into account. In considering where to set dose limits. Dose limits are set at a level below which the risk is regarded as acceptable. However, as a prudent measure, it is assumed that every exposure to radiation, even if under the dose limit, carries some risk; therefore, regulations require to reduce all doses to levels that are ALARA. ALARA is not a dose limit, but a practice that aims to keep dose levels as far as possible below the regulatory limit. In fact, the total radiation dose attributable to the nuclear industry represents only a tiny fraction of that dose; i.e. in the range of12–18 micro Sieverts (μSv), which is thousands of times lower than the limit. The linear non-threshold model (LNT) is a risk model used internationally by most health agencies and nuclear regulators to set dose limits for workers

and members of the public. The LNT conservatively assumes there is a direct relationship between radiation exposure and cancer rates [18, 19].

1.9.3. How Radiation Affects Cells

Radiation affects our health primarily through breakage of deoxyribonucleic acid (DNA) molecules. DNA is a long chain of amino acids whose pattern forms the blueprint on how a cell lives and functions, and radiation is able to break that chain. When it does, three things can happen [20].

a) The cell is repaired properly and it continues to function normally. DNA breakage occurs normally every second of the day, and cells have a natural ability to repair that damage.

b) When the DNA or other critical parts of a cell receive a large dose of radiation, the cell may die or be damaged beyond repair. If this happens to a large number of cells in a tissue or organ, early radiation effects may occur. These early effects are called "deterministic effects" and their severity varies according to the radiation dose received. They can include burns, cataracts and, in extreme cases, death [20] . The first evidence of deterministic effects became apparent with early experimenters and users of radiation. They suffered severe skin and hand damage due to excessive radiation exposure. More recently, such effects were observed during the 1986 Chernobyl nuclear plant accident where more than 130 workers, and fire fighters received high radiation doses (800 to 16,000 mSv) and suffered severe radiation sickness. Two of the people exposed died within days of exposure, and close to 30 more workers and firefighters died within the first three months. The international regulators have put measures in place – including stringent dose limits and databases to track radioactive sources – to mitigate the chances of the public or workers receiving radiation doses high enough to cause deterministic effects [20].

In some cases, part of the DNA in the cell may be damaged by radiation and may not properly repair itself. The cell may continue to live and even reproduce itself. However, during that process, errors that have not been repaired in the DNA chain will also be present in the cell descendants and may disrupt these cells' functioning. This type of detrimental effect has a probability that is proportionate to the dose, and is called a "stochastic effect." With stochastic effects, the likelihood of effects increases as the dose increases. However, the timing of the effects or their severity does not depend on the dose. DNA damage happens continuously in the human body. People experience about 15,000 DNA damage events that do not result in cell death, every second of every day [20] . After a cell is damaged, its structure can change due to improper repair; this alteration could have no further effect, or it could result in effects, such as cancer and hereditary effects, which show up later in life. If the DNA of sperm or egg cells is

damaged, genetic damage occurs. This damage can result in a harmful characteristic that can be passed on from one generation to the next. Animal studies, such as those conducted on fruit flies by Hermann J. Muller in 1926, showed that radiation will cause genetic mutations. However, to date, genetic effects caused by radiation have not been observed in humans. This includes studies involving some 30,000 children of survivors of the atomic bombings of the Japanese cities of Hiroshima and Nagasaki, in 1945 (BEIR VII) [21] .

1.10. Radiation Doses

For the purpose of radiation protection, dose quantities are expressed in three ways: absorbed, equivalent, and effective.

1.10.1. Absorbed Dose (D)

When ionizing radiation penetrates the human body or an object, it deposits energy. The energy absorbed from exposure to radiation is called an absorbed dose. The absorbed dose is measured in a unit called the gray (Gy). A dose of one gray is equivalent to a unit of energy (Joule) deposited in a kilogram of a substance [21].

1.10.2. Equivalent Dose (H)

When radiation is absorbed in living matter, a biological effect may be observed. However, equal absorbed doses will not necessarily produce equal biological effects. The effect depends on the type of radiation (e.g., alpha, beta or gamma) . For example, 1 Gy of alpha radiation is more harmful to a given tissue than 1 Gy of beta radiation. To obtain the equivalent dose, the absorbed dose is multiplied by a specified radiation weighting factor (w_R). A radiation weighting factor is an estimate of the effectiveness per unit dose of the given radiation relative to low-LET standard and used to equate different types of radiation with different biological effectiveness as show in table (1.1). The equivalent dose is expressed in a measure called the sievert (Sv). This means that 1 Sv of alpha radiation will have the same biological effect as 1 Sv of beta radiation. In other words, the equivalent dose provides a single unit that accounts for the degree of harm that different types of radiation would cause to the same tissue [21].

$$H = \Sigma D W_R \qquad 1.3$$

Table 1.1 : Radiation Weighting factors

Radiation Type and Energy Range	Radiation Waiting factor ,W_R
X and γ rays, all energies	1
Electrons positrons and muons, all energies	1
Neutrons:	

< 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, (other than recoil protons) and energy > 2 MeV,	2-5
α particles, fission fragments, heavy nuclei	20

1.10.3. Effective Dose

Different tissues and organs have different radiation sensitivities. For example, bone marrow is much more radiosensitive than muscle or nerve tissue. To obtain an indication of how exposure can affect overall health, the equivalent dose is multiplied by a tissue weighting factor (w_T) related to the risk for a particular tissue or organ where the tissue weighting factors are mandated for use in the field of radiation protection to convert equivalent dose to effective dose. The International Commission on Radiological Protection (ICRP) is the international body that provides the method of calculation for these weighting factors and recommends their use as shown in the table 1.2. This multiplication provides the effective dose absorbed by the body. The unit used for effective dose is also the sievert. For example, if someone's stomach and bladder are exposed separately to radiation, and the equivalent doses to the organs are 100 and 70 mSv respectively, the effective dose is: (100 mSv x 0.12) + (70 x 0.05) = 15.5 mSv. The risk of harmful effects from this radiation would be equal to a 15.5 mSv dose delivered uniformly throughout the whole body [21] .

$$\mathbf{E = \Sigma H_T W_T = \Sigma D W_R W_T} \qquad \mathbf{1.4}$$

Table 1.2: Tissue weighting factors

Organ	Tissue weighting factor, w_T
Gonads	0.20
Colon	0.12
Bone marrow (red)	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Chest	0.05

Liver	0.05
Thyroid gland	0.05
Oesophagus	0.05
Skin	0.01
Bone surface	0.01
Adrenals, brain, small intestine, kidney, muscle, pancreas, spleen, thymus, uterus	0.05

1.10.4. Dose Limits

The recommendations of the ICRP, which comprises some of the world's leading scientists and other professionals in the field of radiation protection, and also uses many of the standards and guides of the International Atomic Energy Agency (IAEA). For people who operate or work with nuclear energy, the regulated dose limit is set below the lower boundary of what is considered unacceptable exposure. For example, effective dose limits for nuclear energy workers are 50 mSv per year and 100 mSv over 5 years. Radiation exposures below an acute dose of approximately 100 mSv have not been shown to increase the risk of health effects such as cancer [22] .

1.11. Natural radioactivity of building materials

All building materials contain various amounts of natural radioactive nuclides. Materials derived from rock and soil contain mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K). In the uranium series, the decay chain segment starting from radium (^{226}Ra) is radiologically the most important and, therefore, reference is often made to radium instead of uranium. The world-wide average concentrations of radium, thorium and potassium in the earth's crust are about 40 Bq kg^{-1}, 40 Bq kg^{-1} and 400 Bq kg^{-1}, respectively [20]. Radiation exposure due to building materials can be divided into external and internal exposure. For example, an inhabitant living in an apartment block made of concrete with average activity concentrations (40 Bq kg^{-1}, 30 Bq kg^{-1} and 400 Bq kg^{-1} for radium, thorium and potassium, respectively) receives an annual effective dose of about 0.25 mSv (excess to the dose received outdoors). Enhanced or elevated levels of natural radionuclides in building materials may cause doses in the order of several mSv per year. The internal exposure is caused by the inhalation of radon (^{222}Rn), thoron (^{220}Rn) and their short lived decay products. Radon is part of the radioactive decay series of uranium, which is present in building materials. Because radon is an inert gas, it can move rather freely through porous media

such as building materials, although usually only a fraction of that produced in the material reaches the surface and enters the indoor air [22].

The most important source of indoor radon is the underlying soil but in some cases and some Member States also the building materials may be an important source. In most cases the main part of indoor radon on the upper floors of a building originates from building materials. Typical excess indoor radon concentration due to building materials is about 10 –20 Bq m^{-3}, but in some zones and in rare cases it may rise up to greater than 1000 Bq m^{-3}. Building materials are the most important source of indoor thoron. However, thoron concentrations are usually rather low. Indoor thoron can be an important source of exposure only under some rare conditions where the building materials contain high concentrations of thorium [21].

Chapter (2)

Radon Gas

2.1. History Of Radon

Friedrich Dorn, a German scientist, discovered in 1900 that radium was giving off a gas which he called radium emanation. A few years later, in 1908, William Ramsey and R.W. Whytlaw-Gray isolated enough of the gas to study its physical properties. As well as finding it was the densest gas known (9.73 g dm^{-3}), they called it niton. In the 1920's, the name radon, symbol Rn, was adopted for all the isotopes of element 86. Though radon was not discovered until 1900, the effects of prolonged exposure to high levels had been noted over 300 years earlier. Two researchers in the first half of the sixteenth century, Georgius Agricola (a German physician and geologist, 1494 to 1555) and Paracelsus (a Swiss physician, alchemist and scientist, 1493 to 1541) studied the diseases of underground miners in Europe. They found that many miners died early because of lung diseases, and concluded that the causes were dust and gases in the mines. Studies in more recent times have shown that high radon levels in mines in many parts of the world are linked to a higher risk of lung cancer [23] .

2.2. Radon Gas Properties and Sources

Radon is a natural radioactive gas without odour, colour or taste. It cannot be detected without special equipment. Radon occurs as a product of uranium decay. Uranium is a natural radioactive material found in varying amounts in all rocks, soil, concrete and bricks. It occurs everywhere on earth, especially in rocky and mountainous areas. Radon is an unstable radionuclide that disintegrates through short lived decay products before eventually reaching the end product of stable lead. The short lived decay products of radon are responsible for most of the hazard by inhalation. Radon and its decay products called radon daughters or radon progeny emit highly ionizing alpha-radiation. Decay products are suspended in the air which we breathe. Although the risk is very low when radon is diluted to extremely low concentrations in the open, radon in room air typically contributes up to 50% to the background radiation (Figure 2.1). However, in places such as caves and mines, it can accumulate up to dangerous concentrations and may cause substantial health damage after long-term exposure. Radon can also be found in drinking water and this can sometimes present a hazard. Certain types of geology, such as granite and volcanic soils, as well as aluminous shales, are more likely to contain radon. Conversely, low concentrations of this gas are expected in sedimentary rocks [23].

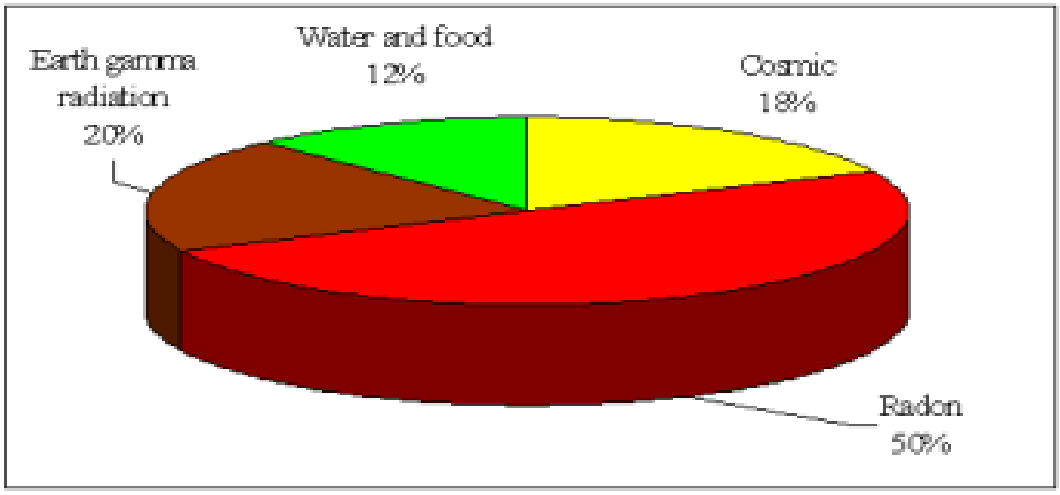

Figure 2.1: Sources and average distribution of natural background radiation for the world population (UNSCEAR, 2000).

2.3. Radon Isotopes

The nucleus of an atom consists of protons and neutrons. An isotope is one of two or more atoms having the same atomic number (number of protons), but different mass numbers (number of neutrons). Radon has no stable isotopic form; all of its isotopes are radioactive. There are three naturally occurring isotopes of radon:

a) Radon-222 is formed from the decay of Uranium-238 as part of a series of transformations referred to as a decay chain (see Figure 2.2). With a half-life(3.82 day). Radon-222 is the radon isotope that causes the most concern, because of the natural abundance of Uranium-238 in the earth's crust and the health effects of its further decay products.

b) Radon-219 is formed during the decay of Uranium-235 with half- life (4 S) [23].

c) Radon-220 (also known as thoron) is formed during the decay of Thorium-232 with half- life (55 S) [23].

2.4. Decay Products

When uranium decays, it goes through a series of 14 transformations called a decay chain. This process takes several billion years to complete. At the end of radon's decay chain is Lead-206, a stable, non-radioactive element. Radon-222 belongs to the radium and Uranium-238 decay chain and has a half-life (the time that the original amount has taken to decay to one half) of 3.8 days. In turn, radon decays into a series of solid, short-lived radioisotopes called radon progeny or radon decay products (RDPs). Due to their short half-lives, radon progeny emit radiation more quickly and present greater health risks than radon itself. Two decay products of radon, Polonium-218 and Polonium-214, pose a major health risk because they emit alpha radiation [23], which

has a greater relative biological effectiveness (the ability to cause a biological effect) than beta or gamma radiation.

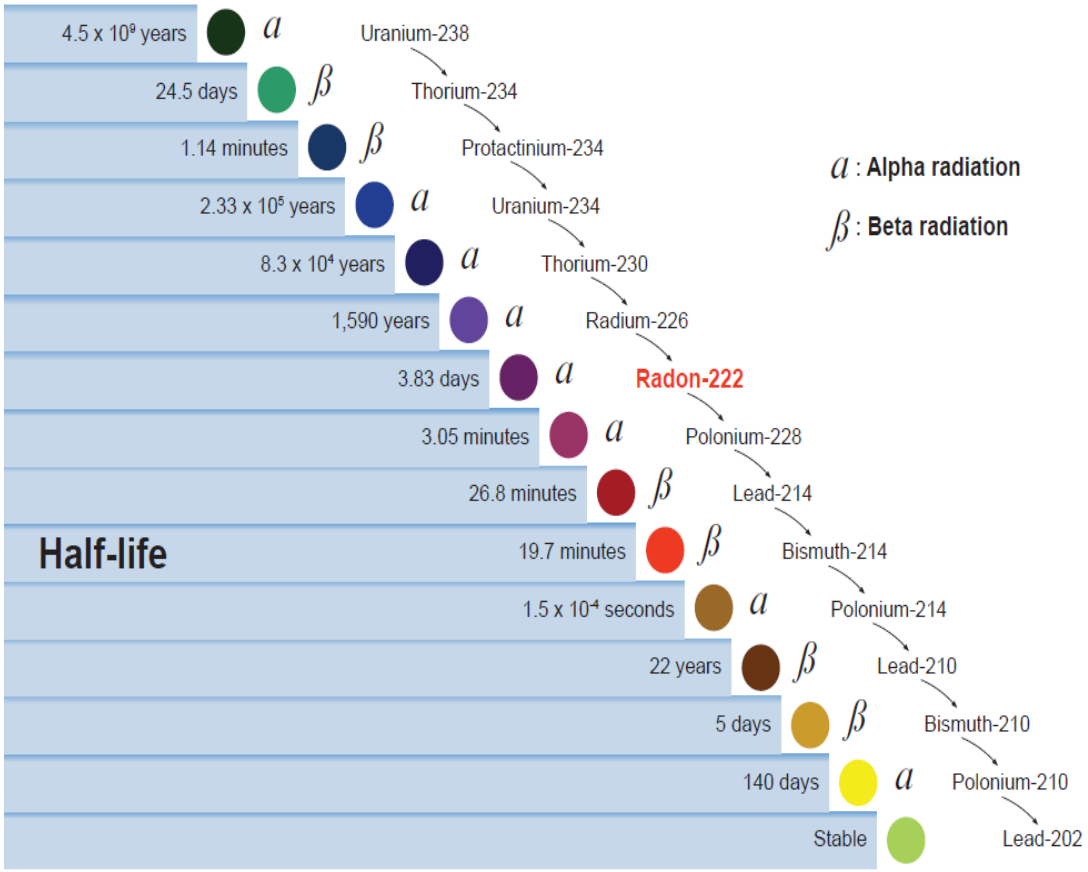

Figure 2.2: Uranium-238 Decay chain

2.5. Radon Enter Houses

Radon gas can move through small spaces in the soil and rock upon which a house is built. It can seep into a home through dirt floors, cracks in concrete, sumps, joints, basement drains, under the furnace base and jack posts if the base is buried in the floor. Concrete-block walls are full of tiny pores and can allow fluids or gas such as radon to pass through and be released into the air. Radon trapped in well water can also be released into the air when the water is used in the home [24].

2.6. Reducing Radon Levels in Existing Houses

One or more of the following methods may be used to reduce the radon level in an existing building. A 'sump' and extract pipe can be installed beneath the floor, from outside. A fan can be fitted to draw out the radon and blow it into the atmosphere above the roof of the house. Gaps between the ground floor and walls and gaps around service pipes can be sealed. Positive pressurization of the house using a fan in the

roof-space prevents gas entering, i.e. making the air pressure inside slightly higher than outside. Also natural or forced ventilation of the void under the ground floor will reduce radon levels [25].

2.7 How to Prevent High Levels in New Buildings

New buildings are generally protected by full protection to a suspended concrete ground floor. In this the radon-proof barrier is positioned over the floor structure and linked to cavity trays at the edges. Supplementary protection is also provided by locating under floor vents on two or more sides of the under floor space. If necessary the rate of ventilation and radon dispersion can be increased by fitting an electric fan at a later date. The radon barrier comprises of a cavity tray through the wall linked to a membrane across the floor. This is then sealed to a 300 μm poly ethane membrane laid across the beam and block floor. To make it easier to seal the two materials the cavity tray is laid so that it laps about 300mm over the edge of the floor. The membrane over the floor can then be sealed to the cavity tray using a double sided butyl jointing strip just prior to installing the floor topping. Airbricks are installed where possible on all sides of the building at intervals at least as frequent as would be normal for an ordinary suspended timber floor [25].

2.8. Health Effects of Radon

The adverse health effects of exposure to radon are caused primarily by damage due to alpha-particles. The possible effects will depend on exposure level. The main danger from high radon exposure is an increased risk of lung cancer. Radon as a noble gas is rapidly exhaled after being breathed in; however, radon progeny, combine with other molecules in the air and with particles of dust, aerosols or smoke, and readily deposit in the airways of the lung. While lodged there, the progeny emit ionizing radiation in the form of alpha particles, which can damage the cells lining the airways. Experiments have confirmed that ionizing radiation affecting bronchial epithelial cells could cause cancer. Epidemiological studies on thousands of uranium miners in different countries, including Germany, USA, Canada, Czechoslovakia, and others, also support this fact. Analyses have been undertaken of several miner studies, totaling 68,000 men of whom 2,700 died from lung cancer. An increased risk of all histological types of lung cancer, including small cell carcinoma, adenocarcinoma, and squamous cell carcinoma, has been associated with occupational exposure to radon.

But exposure to radon in houses can also lead to lung cancer. It is believed, for example, that every year more than 15 000 deaths from lung cancer occur due to radon exposure in the United Sates and more than 2 500 deaths in the United Kingdom. Lung cancer risk is much higher when radon exposure is combined with smoking. According to the BEIR IV report of the US National Academies of Sciences, for men exposed to radon at work, smokers were 10 times more likely to get lung cancer risk than non-smokers. The risk of lung cancer from radon in home can be estimated by two ways: by direct epidemiological studies of residential radon and by projecting occupational risk estimates to lower levels of radon in homes. The uncertainties associated with residential studies are larger than those with miner studies, primarily because the risk is smaller at the low exposures encountered in most homes. It is also difficult to estimate the radon exposures that people have received over their lifetimes, probably in several houses. Despite the uncertainties , it is clear that far more lung cancers are caused by smoking than are caused by radon. It is believed that the relationship between radon and risk of lung cancer is linear. In other words, doubling the exposure doubles the risk and halving the exposure halves the risk. Doubling of the risk means much more for a smoker, who is already at high risk of lung cancer, than for a non-smoker with a very small base line risk. Lung cancer risk from residential radon exposure is substantially lower since the exposure in homes is much lower than in mines, although the risk increases with radon concentration level and duration of exposure. For life-time exposure to radon of 20 Bq/m3 level at home the risk of lung cancer is estimated to be 0.3% (or 3 deaths in 1000 people). For comparison, risk of accidental death at home is 0.7% (or 7 in 1000). It has been suggested that other effects of radon exposure include increased risk of nonmalignant respiratory diseases but this is much less clearly established than the lung cancer risk. It is still not clear whether children are more sensitive to radon exposure. Studies on childhood leukaemia (the most common form of cancer in childhood) have not found clear evidence of risk associated with radon concentrations in homes [26].

2.9. Units are used to Express Radon Gas Concentrations and Radon Exposure:

The activity (rate of decay) of (^{222}Rn) is expressed in units called curies. The Curie is based on the rate of decay of one gram of (^{226}Ra) or 3.7 x 10^{10} disintegrations per second. The International System of Units (SI) measure of activity is Becquerels per cubic meter (Bq/m^3). One Bq equals 1 disintegration per second. Historically, (^{222}Rn) exposure rates have been expressed as working levels (WLs); 1 WL equals any combination of short-lived (^{222}Rn) (^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po) in 1 liter of air that releases 1.3 x 105 MeV of potential alpha energy [29]. The value of 1.3 x 105 MeV derives from the energy produced by complete decay of the short-lived (^{222}Rn) progeny in radioactive equilibrium with 100 pCi/L of (^{222}Rn). A unit that incorporates both dose and time is the working level month (WLM). Exposure to 1 WL for 1 working month (170 hours) equals 1 WLM cumulative exposure. The SI unit of cumulative exposure is expressed in joule-hours per cubic meter (Jh/m^3). One WLM is equivalent to 3.5 x 10^{-3} Jh/m^3 [26] .

2.10. The Uses of Radon

Radon is still produced for therapeutic use by a few hospitals by pumping it from a radium source and sealing it in minute tubes, called seeds or needles, for application to patient. This practice has been largely discontinued as hospitals can get the seeds directly from suppliers, who make up the seeds with the desired activity for the day of use. There are still places where bathing in radon laden water is thought to be healthy for the body and soul. One such place is the Rudolf-Stollen mine that uses radon inhalation as a healing tool. A radon monitoring method is employed in the Chuko fault zone in south central Taiwan for earthquake prediction. Soil gas radon is monitored continuously with a solid-state detector and recorded with a data logger. The detector assembly is housed in a PVC pipe to reduce the influence of environmental factors. The fault zone is known to have deep source gases and sensitive to earthquake activities. The quantities of natural gas releases are known to vary with earthquake activities. Data retrieval from the end of October 2000 to the end of February 2001, showed that spike-like radon anomalies, i.e. rapid increases in the

amount of radon, occurred before every major earthquake with a magnitude of more than 4.0 on the Richter scale. The strong correlation between spike-like anomalies and major earthquakes suggests that this might become a method of earthquake prediction [28].

2.11. Measuring Radon Concentration Techniques

Radon measurements are often discussed in terms of either a short-term or long-term test. A short-term test for radon, using an activated charcoal detector or another type of detector such as an electret ion chamber, can provide a first indication of the mean long-term radon concentration in a home. However, diurnal and seasonal radon variations should be taken into account when performing short-term radon measurements. Since high radon concentrations commonly occur during periods when homes are "closed up" (i.e. windows closed), a short-term measurement performed during this period, or season, can overestimate the yearly mean radon concentration. Alternatively, a short-term radon measurement performed during a period when the house has increased ventilation (e.g. windows open) can substantially underestimate the mean annual radon concentration. Therefore, in order to assess the annual average radon concentration within a home, devices that provide a long-term integrated radon measurement are preferred. However, it should be noted that even yearly radon concentrations in the same home can vary. The most popular radon measuring devices (Table 2.1) used by countries surveyed within the WHO International Radon Project were passive nuclear-track detectors(NTDs), electret ion chambers (EICs), and activated charcoal detectors (ACDs). Active devices in use by many countries included electronic integrating devices (EIDs) and continuous radon monitors (CRMs). Passive devices do not require electrical power or a pump to work in the sampling setting, whereas active devices require electricity and include the ability to chart the concentration and fluctuations of radon gas during the measurement period. For homes, NTDs are a popular choice to obtain a long-term radon measurement and are often deployed for a one-year period, while EICs are often used for short to intermediate measurement periods. The use of CRMs has become more prevalent as the price of these detectors has slowly declined [29].

Table 2.1: Radon gas measurement devices and their characteristics.

Detector Type	Passive/Active	Typical Sampling period	Cost
Nuclear-Track Detector (NTD)	Passive	1-4 months	low
Activated Charcoal detector(ACT)	Passive	2-7 days	low
Electret Ion Chamber (EIC)	Passive	5 days-1 year	Medium
Electronic Integrating devices (EID)	Active	2 days	Medium
Continuous Radon Monitor (CRM)	Active	1 hour	High

2.12. Solid State Nuclear Track Detectors

The field of Solid State Nuclear Track Detection had its origin in the year 1958 when first observations were reported by D. A. Young at AERE Harwell (Young, 1958). A solid-state nuclear track detector or SSNTD (also known as an etched track detector or a dielectric track detector, DTD) is a section of a solid material (photographic emulsion, crystal, glass or plastic) uncovered to nuclear radiation (neutron or charged particles, intermittently as well gamma rays), etched, and inspected microscopically. The pathway of nuclear particles are imprinted quicker than the body substance, in addition to the range and form of these trails acquiesce knowledge regarding the charge, mass, direction of motion of the particles as well as the energy. The benefits over other radiation detectors include the detailed knowledge accessible on distinctive particles, the insistence of the passageways permitting measurements to be made over extended periods of time, and the easy, inexpensive and active construction of the detector. The foundation of SSNTDs is that charged particles break the detector within nanometers down the path in such a way that the path can be imprinted persistently more rapidly than the pure substance. Etching, characteristically for some hours, extends the dent to narrowing depths of micrometer dimensions, which can be seen with a microscope. For an identified particle, the distance of the pathway shows the energy of the particle. SSNTDs are frequently used to learn more about cosmic rays, long- standing radioactive elements, radon concentration in houses, and the age of geological samples [30] .

2.12.1. Some useful features of track detectors

1. They are inexpensive, convenient to use and quite robust.

2. Rapid and automatic techniques can be employed with these detectors to count the number of events occurring.

3. They can be obtained in any size, from very small to very large (small detectors can be used to measure particle fluxes in odd locations while large detectors are used to record very rare events in cosmic ray studies).

4. They are insensitive to β, γ and X -radiation.

5. They are insensitive to light. Their development or etching is simple and rapid and does not require dark room facilities.

6. The registered tracks are a permanent record of the phenomenon under investigation. In particular, they remain unaffected by changes in atmospheric conditions such as temperature, pressure, humidity etc.

7. They can be used as threshold detectors, e.g. glasses and certain plastics record fission fragment tracks.

8. The charge and energy discrimination of these detectors has been found to be better than that of nuclear emulsions [30] .

Chapter (3)

Experimental Work

3.1. Introduction

This study were done during the month of March to July 2015, which include the following main stages**,** where the samples are collected from destroyed building materials and fresh building materials.

3.2. Materials and Experimental Methods

3.2.1. Samples' Collection

Different samples of destroyed building materials after the 2014 war against Gaza were collected randomly from different destroyed buildings, like, houses, commercial companies, and factories, all around the area of study during the month of March to July. Samples were a red brick, marble, ceramic, concrete, tiles asbestos, glass and building stones, samples were from different origins, used in construction of building in Jabalia district, Gaza Strip, Palestine. Samples were then identified and given a number and an identifying symbol which identify the location of the samples, as in Table 3.1.

3.2.2. Samples' preparation

5 kg from each sample were collected and dried in a temperature controlled furnace (oven) at a temperature100°C for two hours to ensure that moisture was completely removed. And then the samples were crushed to a fine powder and sieved through a small mesh size to remove the larger grains size and render them more homogenous. The respective net weights of the samples ready for measurement were recorded.

Table 3.1: List of numbers and codes for samples studied in this research

Sample NO.	Sample code	Type	Sample NO.	Sample code	Type
1	G1	ceramic	21	A1	building stones
2	G2	ceramic	22	A2	building stones
3	G3	ceramic	23	A3	building stones
4	G4	ceramic	24	A4	building stones
5	G5	ceramic	25	A5	building
6	F1	red brick	26	D1	marble
7	F2	red brick	27	D2	marble
8	F3	red brick	28	D3	marble
9	F4	red brick	29	D4	marble
10	F5	red brick	30	D5	marble

11	B1	concrete	31	H1	asbestos
12	B2	concrete	32	H2	asbestos
13	B3	concrete	33	H3	asbestos
14	B4	concrete	34	H4	asbestos
15	B5	concrete	35	H5	asbestos
16	E1	tiles	36	C1	glass
17	E2	tiles	37	C2	glass
18	E3	tiles	38	C3	glass
19	E4	tiles	39	C4	glass
20	E5	tiles	40	C5	glass

3.2.3. Preparation of "Dosimeters"

The close vessel technique was used in this study "can technique" or we call them "Dosimeters". Dosimeters are plastic cylindrical vessels of volume (7.93×10^{-4}) m^3 with cross sectional area of (5.02×10^{-3} m^2) as shown in Figure 3.1. The destroyed building material samples were put at the bottom of these vessels. About 200 g of each sample was placed in a plastic can of dimensions15.8 cm in height and 8 cm in diameter.

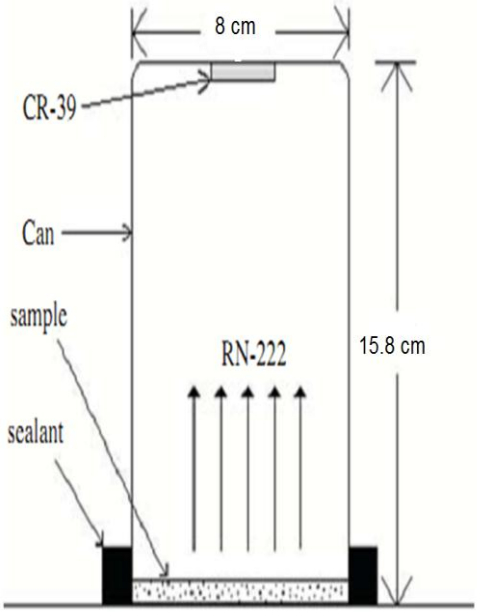

Figure 3.1 Experimental set up for Radon Detector

The use of plastic solid-state nuclear track detectors, SSNTDs of type CR-39, which were cut into small pieces,2cm×2cm and fixed on the top of inner surface of the can, in such a way that its sensitive surface always facing the sample. The can was sealed air tight with adhesive tape and kept for assessment of radon exhalation for exposure

evaluation over three months. During the exposure period (one hundred and twenty four days), the detector was exposed freely to the emergent radon from the sample in the can so that it could record alpha particles resulting from the decay of radon in the remaining volume of the can [31] .

3.2.4. Collecting Detectors and Chemical Etching

After the mentioned period, forty detectors were taken out of the dosimeters. The detectors were then chemically etched in 6 N-solution of Sodium Hydroxide (NaOH) at a temperature of 70 C for four hours and one third of an hour. The etching process was performed at chemistry Laboratories at An-Islamic University using the setup. In addition, the function of the condenser is to keep the concentration of the NaOH solution constant, and the function of the thermometer is to make sure that the temperature is constant during the whole period of the etching process. After four hours and one third of an hour detectors were washed by running and distilled water and then dried to remove any remaining amount of the etchant from the surface of the detectors. By now alpha tracks formed on the detectors were ready for scanning and counting.

3.2.5. Detectors scanning, and counting tracks:

A digital optical microscope with 400 times magnification was used to count the number of tracks per field of view; about ten fields of view were scanned randomly for each detector. Tracks of alpha particles emitted by radon in a CR-39 detector were scanned by the microscope as shown in Figure 3.2. The area of the field of view was calculated by the digital microscope and found to be equal about 5.3×10^{-3} cm^2 ; the average number of tracks per field of view was used to calculate the track density. The calculated track density was converted into radon concentrations in Bq/m^3 using the calibration factor (k) obtained by the standard manufacturer, where every track per cm^2 per day on the CR-39 detectors corresponds to an exposure of 12.5 Bq/m^3 for the activity of radon gas and its daughters and we use previous calibrations [8].

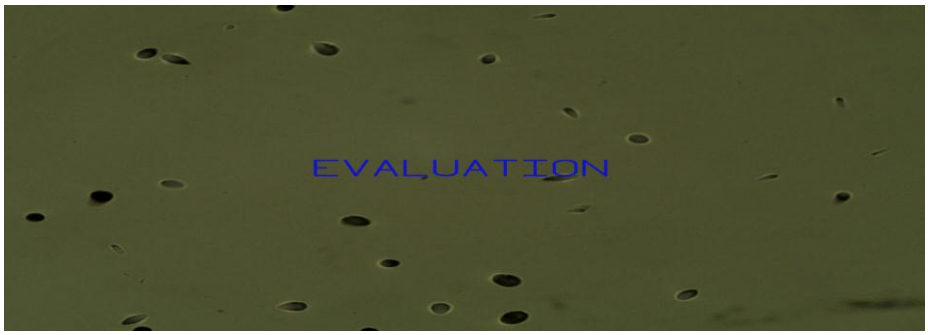

Figure 3.2: Tracks of alpha particles emitted by radon in a CR-39 detector. One viewing field from the microscope has the area of about 0.53 mm^2

3.3. Calculations

The radon concentrations, radon exhalation rate were calculated using the experimental measured average track densities according to the following relations from previous studies [32, 33].

3.3.1. Determination Radon Concentration in Area

$$C_{Rn} = k\frac{\rho}{T_{eff}} \qquad 3.1$$

C_{Rn}: is the radon concentration (Bq/m^3)

K: is the calibration factor = 12.5 Bqm^{-3}/tracks cm^{-2}h^{-1}[8].

ρ: Is the track density (tracks/cm^2)

T_{eff} : effective time =[t + ($e^{-\lambda t}$ - 1)/λ]

t : exposure time

3.3.2. Determination radon exhalation rate in area

The radon exhalation rate (Ex) of any sample is defined as the flux of radon released from the surface of material. The surface exhalation rate in the building material samples was calculated using equation (3.2) , the radon exhalation rate in terms of area (surface exhalation rate) in units of Bq·m^{-2}·h^{-1} can be obtained by as [32, 33].

$$E_x = \frac{CV\lambda}{A[t + (e^{-\lambda t} - 1)/\lambda]} \qquad 3.2$$

Where :

C: is the integrated radon exposure (Bq·m^{-3}·h);

V: is the volume of air in the cup (m^3) = 7.942×10^{-4}m^3

λ: is the decay constant for Rn^{222} (h^{-1}) = 7.56×10^{-3}h^{-1}

A: is the surface area of the sample (m^2) = $5.0265\times10^{-3} m^2$

t: is the exposure time (h) = 124 days = 2976h

3.3.2. Determination Radon Exhalation Rate in Mass

The mass exhalation rate ($Bqkg^{-1}\cdot h^{-1}$) in the building material samples is calculated using the following formula:

$$E_M = \frac{CV\lambda}{M[t + (e^{-\lambda t} - 1)/\lambda]} \qquad 3.3$$

Where E_M is the mass exhalation rate in ($Bqkg^{-1}\cdot h^{-1}$) and M is the mass of sample(kg) [33, 34, 35].

3.3.3. Determination the Annual Effective Dose

The following equation was used to calculate the annual effective dose:

$$\text{Dose} = \epsilon\, f_{Rn}\, T_y\, C_{Rn} \qquad 3.4$$

Where:

f_{Rn}: is the conversion factor = 9 nSv / (Bq h m-3) [33].

T_y: is the time spent indoors per year = 7000 hours

ϵ: is the equilibrium factor (= 0.4)

C_{Rn} : is the radon concentration.

Substituting the previous parameters in equation (3.4) we can evaluate the annual effective dose simply according to the following relation [34].

$$\text{Dose (mSv/y)} = 0.0252 \text{ x } C_{Rn} \qquad 3.5$$

Chapter (4)

Results and Discussion

4.1. Results and Discussion

Results and discussion for radon concentrations, radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m for destroyed building material samples used in Jabalia city are given in this chapter. Equations 3.1, 3.2, 3.3 and 3.5 respectively were used for calculating radon concentrations, radon exhalation rate in term of area , E_x, radon exhalation rate in terms of mass, E_m, and Annual Dose for destroyed building material samples used in this study which include a red brick, marble, ceramic, concrete, tiles, asbestos, glass, and building stones. The results of Radon concentration only is shown in table 4.1 for all building materials.

Table 4.1: Radon concentration for all destroy building material samples used in Jabalia city.

Sample NO.	Sample code	Type	C_{Rn} (Bq/m^3)	Sample NO.	Sample code	Type	C_{Rn} (Bq/m^3)
1	G1	Ceramic	64.19	21	A1	building stones	90.34
2	G2	Ceramic	80.83	22	A2	building stones	145.82
3	G3	Ceramic	114.12	23	A3	building stones	128.38
4	G4	Ceramic	205.41	24	A4	building stones	209.22
5	G5	Ceramic	73.70	25	A5	building stones	186.40
Average			**107.65**	**Average**			**152.03**
6	F1	red brick	104.61	26	D1	marble	39.78
7	F2	red brick	114.12	27	D2	marble	77.98
8	F3	red brick	99.85	28	D3	marble	76.08
9	F4	red brick	66.57	29	D4	marble	124.49
10	F5	red brick	38.04	30	D5	marble	102.23
Average			**84.63**	**Average**			**84.11**
11	B1	Concrete	337.60	31	H1	asbestos	267.86
12	B2	Concrete	274.20	32	H2	asbestos	395.96
13	B3	Concrete	383.57	33	H3	asbestos	408.93
14	B4	Concrete	422.24	34	H4	asbestos	492.93
15	B5	Concrete	460.28	35	H5	asbestos	290.05
Average			**375.58**	**Average**			**371.14**

16	E1	Tiles	133.14	36	C1	glass	49.92
17	E2	Tiles	177.52	37	C2	glass	48.90
18	E3	Tiles	190.20	38	C3	glass	114.12
19	E4	Tiles	180.69	39	C4	glass	98.90
20	E5	Tiles	134.87	40	C5	glass	34.23
Average			**163.28**	**Average**			**69.21**

But radon exhalation rate in terms of area E_x , and radon exhalation rate in term of mass E_m , and annual effective dose for Ceramic is shown in table 4.2.

Table 4.2: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from Ceramic samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
1	G1	Ceramic	64.19	80.35	2.02	1.617
2	G2	Ceramic	80.83	101.84	2.54	2.037
3	G3	Ceramic	114.12	142.85	4.53	2.876
4	G4	Ceramic	205.41	255.93	6.45	5.176
5	G5	Ceramic	73.70	92.25	2.31	1.857
Ave.			107.65	133.92	3.57	2.7126

As can be noted from the data listed in table 4.2, radon exhalation in terms of area ,$E_{x,}$ rate from Ceramic samples ranged from 80.352 $mBq.m^{-2}.h^{-1}$ for G1 sample to 255.93 $mBq.m^{-2}.h^{-1}$ for the sample G4 with an average value of 133.92 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose average values, respectively, were 107.65 Bq/m^3 , 3.57$mBq.Kg^{-1}.h^{-1}$, and 2.7126 $mSv.y^{-1}$. In comparison with other building material samples one can see that Ceramic samples have a slightly higher radon concentrations than marble, red brick and glass and lower than both asbestos ,Concrete, tiles, building stones. The radon exhalation rate in terms of area E_x , and radon exhalation rate in term of mass E_m , and annual effective dose for Red brick is shown in Table 4.3.

Table 4.3: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from red brick samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
6	F1	red brick	104.61	130.944	3.286	2.636
7	F2	red brick	114.12	142.848	3.583	2.875
8	F3	red brick	99.85	124.992	3.136	2.516
9	F4	red brick	66.57	83.328	2.091	1.677
10	F5	red brick	38.04	47.616	1.195	0.958
Ave.			84.63	105.945	2.658	2.1324

As can be noted from the data listed in Table 4.3, radon exhalation rate from red brick samples ranged from 47.616 $mBq.m^{-2}.h^{-1}$ for F5 sample to 142.848 $mBq.m^{-2}.h^{-1}$ for the sample F2 with an average value of 105.945 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose average values, respectively, were 84.63 Bq/m^3, 2.658 $mBq.Kg^{-1}.h^{-1}$, and 2.1324 $mSv.y^{-1}$. In comparison with other building material samples one can notice that red brick samples have a slightly higher radon concentrations than marble and glass and lower than both asbestos ,Concrete, tiles, building stones and ceramic. The radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m , and annual effective dose for Concrete is shown in Table 4.4.

Table 4.4: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from Concrete samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
11	B1	Concrete	337.60	422.592	10.606	8.507
12	B2	Concrete	274.20	461.280	8.614	6.909
13	B3	Concrete	383.57	479.136	12.050	9.666
14	B4	Concrete	422.24	526.752	13.265	10.640
15	B5	Concrete	460.28	574.368	14.460	11.599
Ave.			375.58	469.017	11.799	9.464

As can be noted from the data listed in table 4.4, radon exhalation rate from Concrete samples ranged from 422.592 $mBq.m^{-2}.h^{-1}$ for B1 sample to 574.368 $mBq.m^{-}$

^{2}.h^{-1} for the sample B5 with an average value of 469.017 mBq.m^{-2}.h^{-1}, and the corresponding radon concentration, radon exhalation rate in terms of mass Em and the annual effective dose average values, respectively were 375.58 Bq/m^{3} , 11.799 mBq.Kg^{-1}.h^{-1} , and 9.464 mSv.y^{-1} . In comparison with other building material samples one can see (Table 4.4) that Concrete have the highest radon concentration of all other materials. The radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m , and annual effective dose for Tiles is shown in Table 4.5.

Table 4.5: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from Tiles samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^{3})	E_x (mBq.m^{-2}.h^{-1})	E_m (mBq.Kg^{-1}.h^{-1})	Dose (mSv.y^{-1})
16	E1	Tiles	133.14	166.414	4.182	3.355
17	E2	Tiles	177.52	221.886	5.577	4.473
18	E3	Tiles	190.20	237.734	5.975	4.793
19	E4	Tiles	180.69	225.848	5.676	4.553
20	E5	Tiles	134.87	168.576	4.237	3.398
Ave.			163.28	204.087	5.129	4.1144

As can be noted from the data listed in table 4.5, radon exhalation rate from tiles samples ranged from 166.414 mBq.m^{-2}.h^{-1} for E1 sample to 237.734 mBq.m^{-2}.h^{-1} for the sample E3 with an average value of 204.087 mBq.m^{-2}.h^{-1}, and the corresponding radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose average values, were163.28 Bq/m^{3}, 5.129 mBq.Kg^{-1}.h^{-1},and 4.1144 mSv.y^{-1} respectively. In comparison with other building material samples one can see Table 4.5 it can be seen that tiles samples have a slightly higher radon concentrations than marble, glass, building stones, ceramic and red brick and lower than both asbestos ,Concrete. The radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m , and annual effective dose for building stones is shown in Tables 4.6.

Table 4.6: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from building stones samples

Sample No.	Sample code	Type	C_{Rn} (Bq/m^{3})	E_x (mBq.m^{-2}.h^{-1})	E_m (mBq.Kg^{-1}.h^{-1})	Dose (mSv.y^{-1})
21	A1	building stones	90.34	112.917	2.838	2.276

22	A2	building stones	145.82	182.263	4.581	3.674
23	A3	building stones	128.38	160.464	4.033	3.235
24	A4	building stones	209.22	261.508	6.573	5.273
25	A5	building stones	186.40	232.985	5.856	4.697
Ave.			152.03	190.025	4.776	3.831

As can be noted from the data listed in Table 4.6, radon exhalation rate from building stones samples ranged from 112.917 $mBq.m^{-2}.h^{-1}$ for A1 sample to 261.508 $mBq.m^{-2}.h^{-1}$ for the sample A4 with an average value of 190.025 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass Em and the annual effective dose average values, were 152.03 Bq/m^3, 4.776 $mBq.Kg^{-1}.h^{-1}$, and 3.831 $mSv.y^{-1}$ respectively. In comparison with other building material samples one can see that building stones samples have a slightly higher radon concentrations than marble, glass, ceramic and red brick and lower than both asbestos ,Concrete and tiles. The radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m , and annual effective dose for marble is shown in Table 4.7.

Table 4.7: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from marble samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
26	D1	marble	39.78	49.722	1.249	1.002
27	D2	marble	77.98	97.468	2.449	1.965
28	D3	marble	76.08	95.094	2.390	1.917
29	D4	marble	124.49	155.602	3.911	3.137
30	D5	marble	102.23	127.779	3.211	2.576
Ave.			84.11	105.130	2.642	2.1194

As can be noted from the data listed in Table 4.7, radon exhalation rate from marble samples ranged from 49.722 $mBq.m^{-2}.h^{-1}$ for D1 sample to 155.602 $mBq.m^{-2}.h^{-1}$ for the sample D4 with an average value of 105.130 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass Em and the annual effective dose average values, were 84.11 Bq/m^3, 2.642 $mBq.Kg^{-1}.h^{-1}$, and2.1194 $mSv.y^{-1}$ respectively. In comparison with other building material samples one can see

(Table 4.7) it can be seen that marble samples have a slightly higher radon concentrations than glass and lower than both ceramic, red brick ,asbestos ,Concrete, building stones and tiles. The radon exhalation rate in terms of area E_x , and radon exhalation rate in term of mass E_m , and annual effective dose for asbestos is shown in Table 4.8.

Table 4.8: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from asbestos samples.

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
31	H1	asbestos	267.86	334.803	8.415	6.750
32	H2	asbestos	395.96	494.918	12.439	9.978
33	H3	asbestos	408.93	511.129	12.847	10.305
34	H4	asbestos	492.93	616.123	15.486	12.422
35	H5	asbestos	290.05	362.539	9.112	7.309
Ave.			371.14	463.895	11.659	9.3528

As can be noted from the data listed in table 4.8, radon exhalation rate from asbestos samples ranged from 334.803 $mBq.m^{-2}.h^{-1}$ for H1 sample to 616.123 $mBq.m^{-2}.h^{-1}$ for the sample H4 with an average value of 463.895 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass Em and the annual effective dose average values, respectively, were 371.14 Bq/m^3, 11.659$mBq.Kg^{-1}.h^{-1}$, and 9.3528 $mSv.y^{-1}$. Comparing with other building materials one can see that asbestos samples have the highest radon concentration after Concrete samples. The radon exhalation rate in terms of area E_x, and radon exhalation rate in term of mass E_m , and annual effective dose for glass is shown in Table, 4.9.

Table 4.9: Radon exhalation rate in terms of area E_x, radon exhalation rate in terms of mass E_m , radon concentration, and the annual effective dose from glass samples

Sample No.	Sample code	Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
36	C1	glass	49.92	62.396	1.568	1.258
37	C2	glass	48.90	61.121	1.536	1.232
38	C3	glass	114.12	142.640	3.585	2.876
39	C4	glass	98.90	123.617	3.107	2.492
40	C5	glass	34.23	42.784	1.075	0.862
Ave.			69.21	86.506	2.174	1.744

As can be noted from the data listed in table 4.9, radon exhalation rate from glass samples ranged from 42.784 $mBq.m^{-2}.h^{-1}$ for C5 sample to 142.640 $mBq.m^{-2}.h^{-1}$ for the sample C3 with an average value of 86.506 $mBq.m^{-2}.h^{-1}$, and the corresponding radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose average values, respectively, were 69.21 Bq/m^3, 2.174 $mBq.Kg^{-1}.h^{-1}$, and1.744 $mSv.y^{-1}$. In comparison it can be seen that glass samples have a slightly lowest radon concentration of all other materials. The radon exhalation rate in terms of area E_x , and radon exhalation rate in term of mass E_m , and annual effective dose for each individual sample collected from Jabalia area are summarized in Table 4.10 .

Table 4.10: Summary of results of the average radon exhalation rate in terms of area Ex, radon concentration, radon exhalation rate in terms of mass Em and the annual effective dose from all destroyed building materials used in Jabalia district using standard calibration [ ].

Sample Type	C_{Rn} (Bq/m^3)	E_x ($mBq.m^{-2}.h^{-1}$)	E_m ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
Concrete	375.58	469.017	11.799	9.464
asbestos	371.14	463.895	11.659	9.3528
Tiles	163.28	204.087	5.129	4.1144
building stones	152.03	190.025	4.776	3.831
Ceramic	107.65	133.92	3.57	2.7126
red brick	84.63	105.945	2.658	2.1324
Marble	84.11	105.130	2.642	2.1194
glass	69.21	86.506	2.174	1.744
Aver.	175.95	219.815	5.550	4.433

The data listed in Table 4.10 clearly show that concrete, tiles, building stones and asbestos are have high radon exhalation rate in terms of area E_x, radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose. But the glass have low radon exhalation rate in terms of area E_x, radon concentration, radon exhalation rate in terms of mass E_m and the annual effective dose.

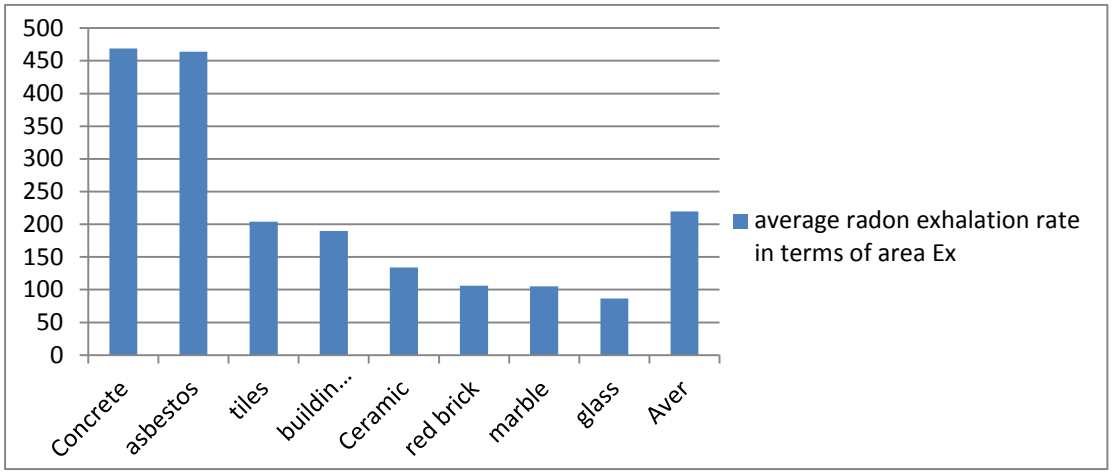

Figure 4.1: Comparing histogram for the average radon exhalation rates in term of area.

The Figure 4.1 comparison between destroyed building materials in terms of the average radon exhalation rates in term of area where the concrete have the highest value with 469.017 $mBq.m^{-2}.h^{-1}$ then asbestos with 463.895 $mBq.m^{-2}.h^{-1}$ then (tiles, building stones, ceramic, ared brick, marble and glass) with(204.087, 190.025, 133.92, 105.945, 105.130 and 86.506) $mBq.m^{-2}.h^{-1}$ respectively. Note that the glass have the lowest value of the materials studied.

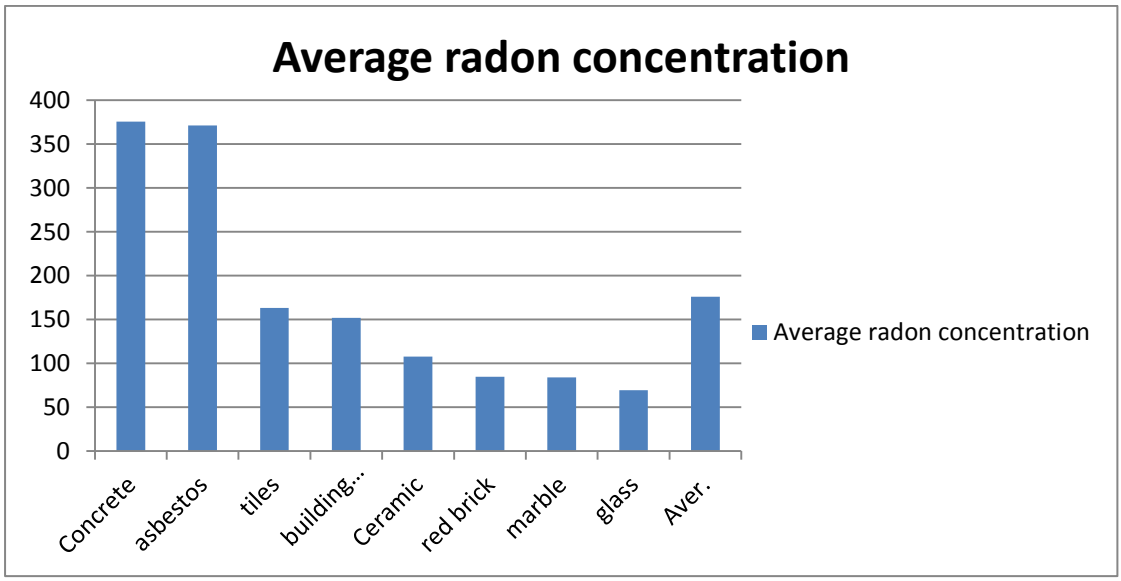

Figure 4.2: Comparing histogram for the average radon concentration rates

The Figure 4.2 comparison between destroyed building materials in terms of the average radon concentration rates where the concrete have the highest value with 375.580 Bq/m^3 then asbestos with 371.140 Bq/m^3 then (tiles, building stones, ceramic,

ared brick, marble and glass) with(163.280, 152.030, 107.650, 84.630, 84.110 and 69.210) respectively. Note that the glass have the lowest value of the materials studied.

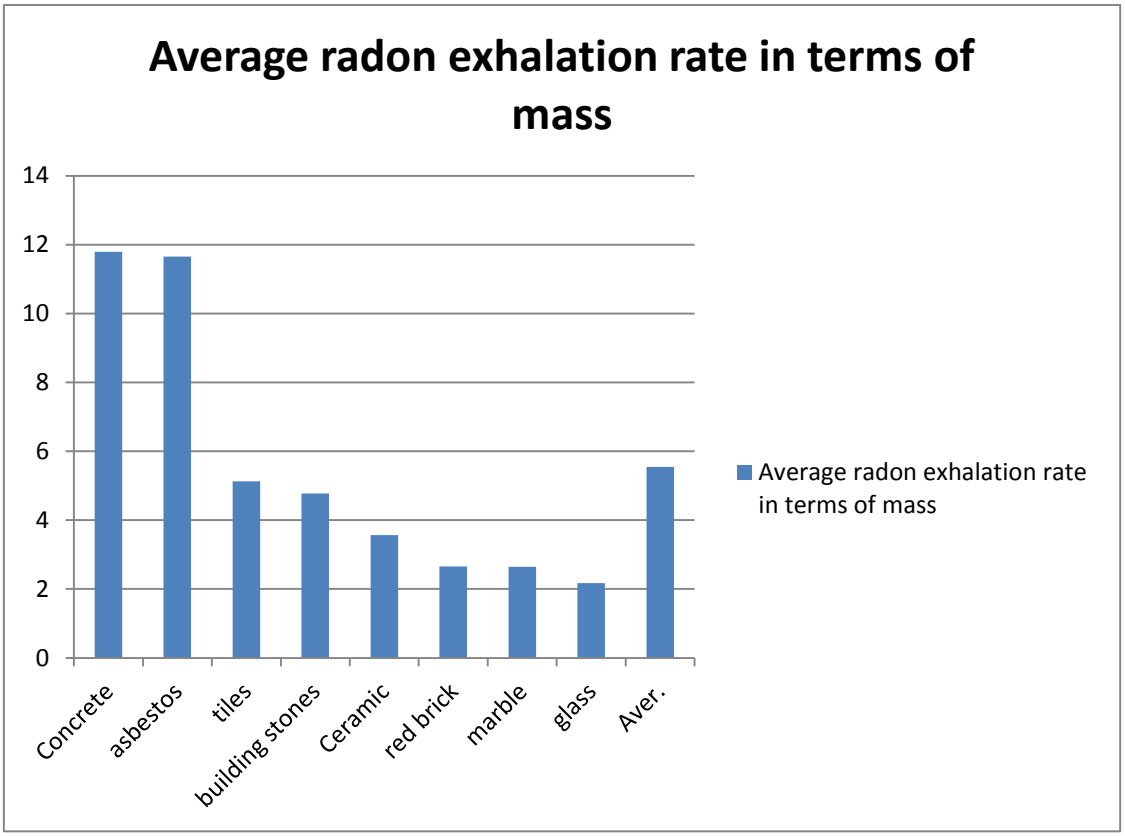

Figure 4.3: Comparing histogram for the average radon exhalation rates in term of mass

The Figure 4.3 comparison between destroyed building materials in terms of the average radon exhalation rates in term of mass where the concrete have the highest value with 11.799 $mBq.kg^{-1}.h^{-1}$ then asbestos with 11.659 $mBq.kg^{-1}.h^{-1}$ then (tiles, building stones, ceramic, ared brick, marble and glass) with(5.129, 4.776, 3.570, 2.658, 2.642 and 2.174) $mBq.kg^{-1}.h^{-1}$ respectively. Note that the glass have the lowest value of the materials studied.

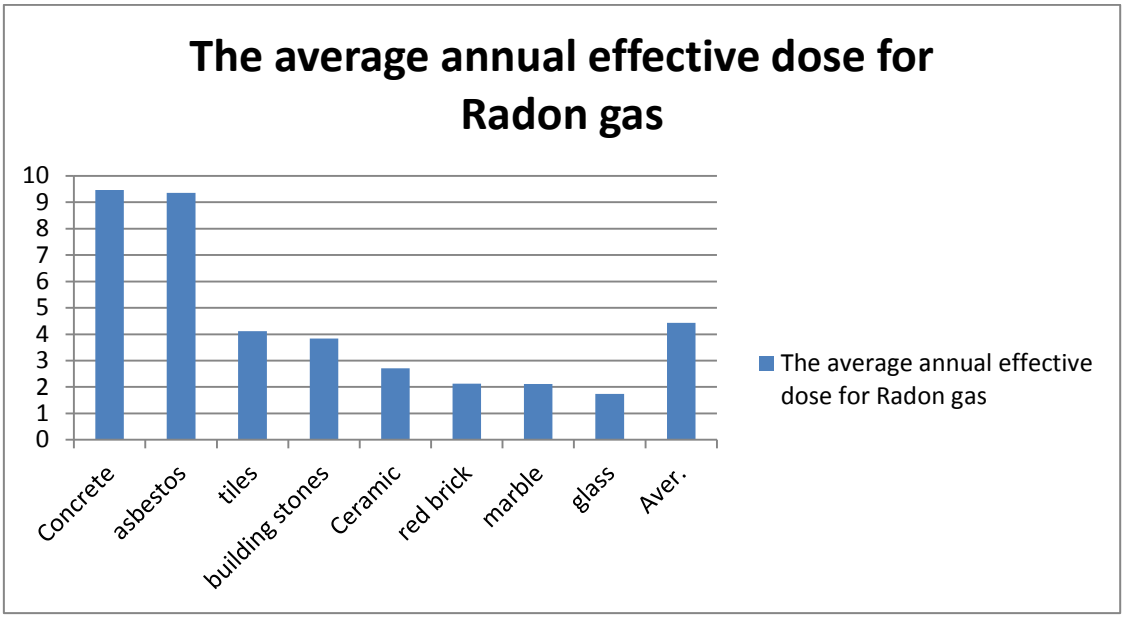

Figure 4.4: Comparing histogram for the average annual effective dose for radon gas.

The Figure 4.4 comparison between destroyed building materials in terms of the average annual effective dose for radon gas where the concrete have the highest value with 9.464 msv.y^{-1} then asbestos with 9.352 msv.y^{-1} then (tiles, building stones, ceramic, ared brick, marble and glass) with(4.114, 3.831, 2.712, 2.132, 2.119 and 1.744) msv.y^{-1} respectively. Note that the glass have the lowest value of the materials studied.

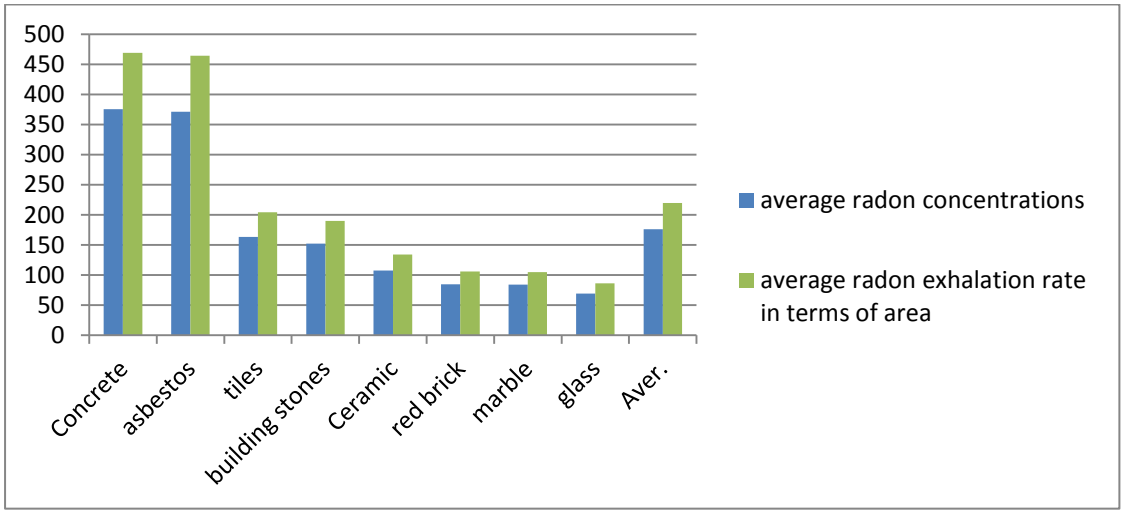

Figure 4.5: Comparing histogram for the average radon concentrations (CRn Ave.) and exhalation rates (E_x Ave.) from building materials used in Jabalia district.

We notice that, the concrete have the highest value of the average radon concentration and the average radon exhalation rate interm of area E_x, then (asbestos, tiles , building stones , ceramic, ared brick , marble and glass) respectively.

4.2. Comparison with previous Studies:

There are many researchers studied radon gas for building materials will show the results obtained:

1-Radon exhalation rates from some building materials used in Sudan published by Abd-Elmoniem A. Elzain, published on 5 June 2014 [33].

Sample Type	CRn (Bq/m^3)	Ex ($mBq.m^{-2}.h^{-1}$)	Em ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
Ceramics	128	240	2.84	3.59
Red brick	190	355	4.21	5.32
Block	197	369	4.37	5.52
Ispistos	214	402	4.76	6.01

We notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 128 Bq/m^3, 240 $mBq.m^{-2}.h^{-1}$, 2.84 $mBq.Kg^{-1}.h^{-1}$ and 3.59 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 107.65 Bq/m^3 ,133.92 $mBq.m^{-2}.h^{-1}$, 3.57 $mBq.Kg^{-1}.h^{-1}$ and 2.712 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for a Red brick equal 190 Bq/m^3 ,355 $mBq.m^{-2}.h^{-1}$, 4.21 $mBq.Kg^{-1}.h^{-1}$ and 5.32 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for a Red brick equal 84.63 Bq/m^3 ,105.94 $mBq.m^{-2}.h^{-1}$, 2.65 $mBq.Kg^{-1}.h^{-1}$ and 2.132 $mSv.y^{-1}$ respectively we notice a big difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon

exhalation rate in terms of mass Em and annual dose for Block equal 197 Bq/m^3 ,369 $mBq.m^{-2}.h^{-1}$, 4.37 $mBq.Kg^{-1}.h^{-1}$ and 5.52 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Block equal 152.03 Bq/m^3 ,190.02 $mBq.m^{-2}.h^{-1}$, 4.77 $mBq.Kg^{-1}.h^{-1}$ and 3.831 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ispistos equal 214 Bq/m^3 ,402 $mBq.m^{-2}.h^{-1}$, 4.76 $mBq.Kg^{-1}.h^{-1}$ and 6.01 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ispistos equal 371.14 Bq/m^3 ,463.89 $mBq.m^{-2}.h^{-1}$, 11.65 $mBq.Kg^{-1}.h^{-1}$ and 9.35 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials.

2- Measurement of Radon Exhalation from Building Materials Used in Nablus District, Palestine published by Fathiya "Husam Al-din" Yousef Shoqwara, published on 12/8/2012 [8].

Sample Type	CRn (Bq/m^3)	Ex ($mBq.m^{-2}.h^{-1}$)	Em ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
marble	240.55	438.79	3.01	6.06
ceramic	193.71	347.42	2.59	4.88
concrete	179.37	325.38	2.46	4.52
building stones	147.00	268.59	1.95	3.70

We notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Marble equal 240.55 Bq/m^3 ,438.79 $mBq.m^{-2}.h^{-1}$, 3.01 $mBq.Kg^{-1}.h^{-1}$ and 6.06 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in

terms of mass Em and annual dose for Marble equal 84.11 Bq/m^3 ,105.13 $mBq.m^{-2}.h^{-1}$, 2.64 $mBq.Kg^{-1}.h^{-1}$ and 2.11 $mSv.y^{-1}$ respectively we notice a big difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 193.71 Bq/m^3 ,374.42 $mBq.m^{-2}.h^{-1}$, 2.59 $mBq.Kg^{-1}.h^{-1}$ and 4.88 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 107.65 Bq/m^3 ,133.92 $mBq.m^{-2}.h^{-1}$, 3.57 $mBq.Kg^{-1}.h^{-1}$ and 2.71 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Concrete equal 179.37 Bq/m^3 ,325.38 $mBq.m^{-2}.h^{-1}$, 2.46 $mBq.Kg^{-1}.h^{-1}$ and 4.52 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Concrete equal 375.58 Bq/m^3 ,469.01 $mBq.m^{-2}.h^{-1}$,11.8 $mBq.Kg^{-1}.h^{-1}$ and 9.46 $mSv.y^{-1}$ respectively we notice a big difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Building stone equal 147.00 Bq/m^3 ,268.59 $mBq.m^{-2}.h^{-1}$, 1.95 $mBq.Kg^{-1}.h^{-1}$ and 3.70 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Building stone equal 152.03 Bq/m^3 ,190.02 $mBq.m^{-2}.h^{-1}$,4.77 $mBq.Kg^{-1}.h^{-1}$ and 3.83 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials.

3- Measurement of Radium Content and Radon Exhalation Rates in Building Material Samples using Passive and Active Detecting Techniques published by Zakariya A. Hussein, Mohamad S. Jaafar and Asaad H. Ismail, Medical Physics, Physics Department, Education College, Salahaddin University -Erbil, 44002, Iraqi Kurdistan, IRAQ, published on September-2013 [36].

Sample Type	CRn (Bq/m^3)	Ex ($mBq.m^{-2}.h^{-1}$)	Em ($mBq.Kg^{-1}.h^{-1}$)
Block	314.15	184.38	17.84
ceramic	237.39	115.85	14.46

We notice that, the radon concentration ,radon exhalation rate interm of area E_x and radon exhalation rate in terms of mass Em for Block equal 314.15 Bq/m^3 ,184.38 $mBq.m^{-2}.h^{-1}$ and 17.84 $mBq.Kg^{-1}.h^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x and radon exhalation rate in terms of mass Em for Block equal 152.03 Bq/m^3 ,190.02 $mBq.m^{-2}.h^{-1}$ and 4.77 $mBq.Kg^{-1}.h^{-1}$ respectively we notice a big difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x and radon exhalation rate in terms of mass Em for Ceramic equal 237.39 Bq/m^3 ,115.85 $mBq.m^{-2}.h^{-1}$ and 14.46 $mBq.Kg^{-1}.h^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x and radon exhalation rate in terms of mass Em for Ceramic equal 107.65 Bq/m^3 ,133.92 $mBq.m^{-2}.h^{-1}$ and 3.57 $mBq.Kg^{-1}.h^{-1}$ respectively we notice a small difference in the values between the two materials .

4-Measurement of Radon Exhalation Rate in Some Building Materials Using Nuclear Track Detectors published by Hesham A. Yousef, A. H. El-Farrash, A. Abu Ela and Q. Merza, Physics Department, Faculty of Science, Suez University, Suez, Egypt, published on 3 July 2015 [37].

Sample Type	CRn (Bq/m^3)	Ex ($mBq.m^{-2}.h^{-1}$)	Em ($mBq.Kg^{-1}.h^{-1}$)	Dose ($mSv.y^{-1}$)
Ceramic	95.29	122.77	1.61	3.00
Marble	219.18	282.38	3.23	6.90

We notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 95.29 Bq/m^3 ,122.77 $mBq.m^{-2}.h^{-1}$, 1.61 $mBq.Kg^{-1}.h^{-1}$ and 3.00 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Ceramic equal 107.65 Bq/m^3 ,133.92 $mBq.m^{-2}.h^{-1}$, 3.57 $mBq.Kg^{-1}.h^{-1}$ and 2.71 $mSv.y^{-1}$ respectively we notice a small difference in the values between the two materials. Also we notice that, the radon concentration ,radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Marble equal 219.18 Bq/m^3 ,282.38 $mBq.m^{-2}.h^{-1}$, 3.23 $mBq.Kg^{-1}.h^{-1}$ and 6.90 $mSv.y^{-1}$ respectively. Comparing with the obtained results presented in the Table(4.10) we notice that, the radon concentration, radon exhalation rate interm of area E_x, radon exhalation rate in terms of mass Em and annual dose for Marble equal 84.11 Bq/m^3 ,105.13 $mBq.m^{-2}.h^{-1}$, 2.64 $mBq.Kg^{-1}.h^{-1}$ and 2.11 $mSv.y^{-1}$ respectively we notice a big difference in the values between the two materials.

Chapter (5)

Conclusion

5.1 Conclusion

Using the closed can technique and the solid state nuclear track detectors (CR-39), we measured the radon exhalation rate from building material samples used in Jabalia in order to assess the contribution of individual material (e.g. red brick , marble, ceramic, concrete, tiles, asbestos, glass, and building stones) to the total indoor radon exposure of the inhabitants of Jabalia district. The corresponding radon concentration, and the annual effective dose were determined and compared with the effective dose limit values recommended by the National Council on Radiation Protection which (from 1 to 5 mSv/y) [21] . Results obtained from the current study show that the radon exhalation rates from asbestos and concrete have relatively high values as compared to other building material samples followed red brick, marble, ceramic, tiles, glass, and building stones contribute less to the indoor radon. From the results of our study we can conclude that the Concrete have the maximum values of radon concentrations 375.58Bq/m^3, radon exhalation rate interm of area469.017mBq.m^{-2}.h^{-1}, radon exhalation in term of mass 11.799 mBq.Kg^{-1}.h^{-1} and the annual effective dose 9.464 mSv.y^{-1}, also asbestos have maximum values of radon concentrations 371.14 Bq/m^3, radon exhalation rate interm of area 463.895 mBq.m^{-2}.h^{-1}, radon exhalation rate interms of mass 11.659 mBq.Kg^{-1}.h^{-1} and the annual effective dose 9.3528 mSv.y^{-1}. But the glass have the minimum values radon concentrations 69.21 Bq/m^3, radon exhalation rate interm of area 86.506 mBq.m^{-2}.h^{-1}, radon exhalation rate in term of mass 2.174 mBq.Kg^{-1}.$h^{-1}$and the annual effective dose 1.744 mSv.y^{-1}. In comparison with the annual effective dose of Radon by NCRP, we found that concrete and asbestos are 9.46 and 9.35 mSv/y, are much higher than the proposed limit which is 1 to 5 mSv/y, and all other material are below the limit. Also the results we obtained are very close to the results obtained from different countries with very small differences which due to the differences in the origin of the building materials and the different in the calibration numbers. Finally the results from destroyed materials and fresh materials are very close which mean that there are no indication about the pollution caused by war at this level of measurements, and it required more advance equipment to be able measure radio nuclei like Uranium and depleted Uranium.

5.2 Recommendations

There are several environmental problems affect the Gaza Strip in the future such as radiation exposure. The major causes to radiation exposure the wars which was done by the Israeli army especially the 2014 war. So I recommend more and more of research work to be done by using modern devices like Gamma detector used as isotope identifier to measure the radiation concentration and the contents of radio nuclei in soil, water, food, air, and building materials. Also more and more of research to be done to discover about causes diseases especially the cancer disease. I recommend to give instructions for the people how to protect themselves by using the media.

Glossary

Absorbed Dose: The amount of energy absorbed, as a result of radiation passing through a material, per unit mass of material. Measured in rads (1 rad = 100 ergs/gm) or grays, the SI unit, where 1 gray =100 rads.

Activity: The strength of a radioactive source, i.e. the number of radioactive atoms decaying per unit of time. Measured in Curies or Bequerels

Alpha Decay : The emission of a nucleus of a helium atom from the nucleus of an element , generally of a heavy element , in the process of its radioactive decay.

Alpha Particle: A particle which is similar to the helium nucleus, consisting of two protons and two neutrons, but is stripped of its orbital electrons. It has a charge of +2 and is the least penetrating of the three common types of radiation. Usually a hazard only occurs when an alpha-emitting substance has entered the body by inhalation, ingestion or absorption through the skin.

Alpha track detector : A long-term detector for radon. It consists of a plastic material or celluloid film, in which alpha radiation leaves damage tracks that can be counted under a microscope after the plastic material is etched in NaOH (sodium hydroxide) solution.

Atom: The smallest particle of an element that exhibits the same chemical properties of the compound itself. Consists of a nucleus (a mass of protons and neutrons) surrounded by electrons.

Atomic Number: The number of protons in the nucleus of an atom.

Atomic Weight: Number approximately equal to the total number of protons and neutrons in the nucleus of an atom, i.e. the mass of an atom .

Background Radiation: Radiation arising from radioactive material other than that under consideration. Background radiation due to cosmic rays and natural radioactivity is always present; there may also be background radiation due to the presence of radioactive substances in building materials **.**

Beta Decay: Radioactive decay in which a nucleus is transformed by the emission of an electron or positron. In either case, the atomic mass remains unchanged, but the atomic number either increases or decreases by 1.

Cancer: A malignant tumor of potentially unlimited growth capable of invading other tissue and of metastasis.

Calibration: The determination of deviation from standard of measurement instrument to determine necessary correction factors (calibration factor).

Cell: The basic structural unit of the body.

Coefficient Of Variation : The standard deviation of a number of samples divided by the average value of those of samples.

Curie (Ci) : A standard measurement for radioactivity, specifically the rate of decay for a gram of radium - 37 billion decays per second. A unit of radioactivity equal to 3.7 x10 disintegrations per second.

Daughter Products : Isotopes that are formed by the radioactive decay of some other isotope.

Decay Product : Radioactive materials degrade to give rise to decay products, often referred to informally as "daughters" or "progeny." The radon decay products of most concern from a public health standpoint are polonium-214 and polonium-218.

Decay Series: The consecutive members of a family of radioactive isotopes formed by sequential radioactive decay.

Dose Equivalent: The sum of the products of the dose equivalent to each organ or tissue and the weighting factors applicator to each of the body organs or tissue that are irradiated. Dose Equivalent uses a newer set of weighting factors that are applicable to more organs and tissues then the Effective Dose Equivalent.

Dose-Rated: Radiation dose per unit time.

Dosimeter: A device used to measure the radiation exposure which a person has received. A film badge, TLD or pocket ionization chamber.

Effective Dose Equivalent: The sum of the products of the dose equivalent to each organ or tissue and the weighting factor applicable to each of the body organs or tissues that are irradiated.

Electretion Chamber: A device for measuring radon. Radon diffuses into the chamber where it goes through its normal decay process emitting ionizing radiation. The ions created alter the charge on an electret surface. Measurements of the charge on the electret surface before and after deployment of the device can be used to calculate the radon concentrations in the room in which the detector was placed.

Electron: An elementary constituent of an atom that orbits the nucleus and has a negative charge. Beta decay is radioactive decay in which an electron (or a positron) is emitted from a nucleus.

Electromagnetic Radiation : A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiation ranges from X-rays(and gamma rays) of short wavelength through the ultraviolet, visible ,and infrared regions to radar and radio waves of relatively long wavelength .

Half-Life: The period of time required for any given radioisotope to decrease to one-half of its original quantity.

Health Physics : The science concerned with the recognition, evaluation, and control of health hazards that may arise from accidents or applications that result in exposure to ionizing radiation.

ICRP: International Commission on Radiological Protection : International body charged with providing an overview of radiation standard and regulations and information to help standardize these regulations.

Ionization :The process whereby a neutral atom or molecule becomes negatively or positively charged by acquiring or losing (an) electron(s).

Ionizing Radiation :Any type of radiation capable of producing ionization in materials it contacts; includes high-energy charged particles such as alpha and beta rays, and non- particulate radiation such as gamma rays and X-rays. In contrast to radiation(e.g., visible light and micro-radio waves) in which the waves do not ionize atoms.

Isotope: An atom of an element characterized by the number of neutrons in the nucleus. All atoms of a given element have the same number of protons, but the number of neutrons can vary among isotopes of the same element.

Ion : An electrically charged atom in which the number of electrons does not equal the number of protons. The ion can have either a positive or negative electrical charge depending on whether it has an excess or a deficit number of electrons.

Irradiate : To expose or cause Exposure to radiation.

Gamma Radiation :Short-wavelength electromagnetic radiation of nuclear origin, with energies between 10 keV to 9 MeV.

Gross Alpha : A measure of the total alpha activity of a water sample, excluding radon. It can serve as a rough indication of the radium and uranium concentrations present in a water sample.

Mass Number: The sum of the number of protons and neutrons in the nucleus of an atom.

Mortar : A mixture of cement, sand, and water, used as a bonding agent for masonry components.

NAS/NRC(National Academy of Science/National Research Council) : The National Academy of Science is private, nonprofit, self-perpetuating society of distinguished scholars involved in scientific and engineering research. As part of NAS , the National Research Council is designed to associate the broad community of science and technology with the needs of the government . The NRC is the operating agency for NAS.

NCRP(National Council on Radiation Protection and Measurements): A nonprofit corporation chartered by congress to provide information that protects the public against radiation and provides recommendations on radiation measurements , quantities and units.

Neutron: One of the two major components of the atomic nucleus. The neutron weighs about as much as the proton, the other major component, and is electrically neutral.

Nuclear Regulatory Commission (NRC) : NRC is an independent agency created from the Atomic Energy Commission in 1975 to regulate civilian uses of nuclear material. Specifically, NRC is responsible for ensuring that activities associated with the operation of nuclear power and fuel cycle plants and the use of radioactive materials in medical, industrial, and research applications are carried out with adequate protection of public health and safety, the environment, and national security.

Nucleus : The central portion of an atom where the protons and neutrons are found.

Nuclide: A specific type of atom characterized by its nuclear properties (i.e., the number of protons and neutrons, and the energy state).

Particle : A tiny mass of material . Airborne particles that exist in the atmosphere as a solid or liquid can be natural , caused by stirring of soil dusts , or anthropogenic.

Photon: A quantum of electromagnetic radiation. The energy of the photon of frequency v is equal to hv where h is Planck's constant.

Positron: An elementary particle with the mass of an electron but unit positive charge.

Organization (RMP) - An individual, sole proprietorship, partnership, corporation, college or university, government agency, laboratory, or institution. The RMP Program treats separate address locations and separate applications are required for each.

Picocurie (pCi) - A Curie is a standard measurement for radioactivity, specifically the rate of decay for a gram of radium--37 billion decays per second. A picocurie (pCi) is one trillionth of a Curie.

Proton : A fundamental unit of matter having a positive charge and a mass number of one**.**

Radioactive decay : A series of isotopes that result following the decay of a parent radionuclide. There are three natural radioactive decay series, uranium-238, uranium-235, and thorium-232.

Radio activity :The release of particles of energy from an atom as it decays. Units of activity are the Becquerel (Bq) and the Curie (Ci).

Radium: A highly radioactive white shining element found in pitchblende, carnotite, and other uranium-containing minerals. It emits alpha particles and gamma rays to form radon.

Radon decay products: means a gaseous radioactive decay product of uranium or thorium.

Radon ready construction: Certain modifications that are made during the construction of a home that would allow for the installation of an active radon mitigation system. Typically these would be aspects of construction that would allow for good negative pressure field extension beneath the slab, such as a layer of large aggregate beneath the slab.

X-RAY: Electromagnetic radiation emitted when orbital electrons of an excited atom return to their ground or normal state (characteristic x-rays). X-Rays are also emitted when high speed electrons strike a metal target (bremmstrahlung).

APPENDIX (I)

The properties of Common Radionuclides Physical Characteristics

Isotope name	Half-time ($t_{1/2}$)	Decay modes and energy (MeV)
Uranium -238(238 U)	2.47×109 years	α,4.198(77%),7.149(23%)
Thorium-234(234Th)	24.1days	β,0.198(72%)
Protactinium-234(234Pa)	1.17 minutes	β,2.29(98%)
Uranium -234(234 U)	2.45×105 years	α,4.773(72%),4.721(27%)
Thorium-230(230 Th)	7.57×104 years	α,4.688(76%),4.621(23%)
Radium-223(226Ra)	1.60×103 years	α,4.785(94%),4.602(6%)
Radon-222(222Ra)	3.8235 days	α,5.49(99.9%)
Polonium-218(218Po)	3.11 minutes	α,6.003(100%)
Lead-214(214Pb)	26.8 minutes	β,0.65(50%) γ,0.295(19%),0.325(37%)
Polonium-214(214Po)	1.64×10^{-4} seconds	α,7.687(100%)
Lead-210(210Pb)	23.34 years	β,0.015(81%)
Bismuth-210(210Bi)	5.01 days	β,1.161(100%)
Polonium-210(210Po)	138 days	α,5.297(100%)
Lead-206(206Pb)	stable	none
Thorium-232(232 Th)	1.39×1010 years	α,4.01(77.8%),3.95(22.1%) γ,0.0638(0.267%)
Uranium -235(235 U)	7.038×108 years	α,4.22(5.7%),4.32(4.4%) 4.40(55%),4.56(4.2%) 4.37(17%). γ,0.196(61%)

Retention is described by (Nuclear Energy Agency { NEA} 1985).

APPENDIX (II)

List of Abbreviations

EPA	Environmental Protection Agency
ATSDR	Agency for Toxic Substances and Disease Registry
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
NIST	National Institute of Standards and Technology
NCI	National cancer Institute
CDC	Center for Disease Control and Prevention
CCNR	Canadian Coalition for Nuclear Responsibility
WHO	World Health Organization
NTDs	Nuclear Track Detectors
ACDs	Activated Charcoal detectors
EICs	Electret Ion Chambers
EIDs	Electronic Integrating devices
CRMs	Continuous Radon Monitors
SSNTDs	Solid-State Nuclear Track Detectors
SD	Standard Deviation
NCRP	National Council on Radiation Protection and Measurements
G	Ceramic
F	red brick
A	building stones
D	marble
B	Concrete
H	asbestos
E	Tiles
C	glass

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الجامعة الاسلامية – غزه
عمادة الدارسات العليا
كلية العلوم
قسم الفيزياء

قياس معدل انبعاث غاز الرادون في مواد البناء المدمرة غزة ـ فلسطين

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رسالة
مقدمة لقسم الفيزياء بكلية العلوم بالجامعة الإسلامية كمتطلب تكميلي لنيل درجة الماجستير في الفيزياء

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ملخص

قياس معدل انبعاث غاز الرادون في مواد البناء المدمرة غزة ـ فلسطين.

أصبح غاز الرادون يعتبر كواحد من أهم المخاطر التي تهدد صحة الإنسان بعد أن لوحظ أنّ التعرض لغاز الرادون يزيد على المدى الطويل من خطر الإصابة بسرطان الرئة. تهدف الدراسة إلى تقييم مساهمة مواد البناء المدمرة في حرب 2014 م التي شنت على قطاع غزه من قبل الجيش الاسرائيلي في زيادة تعرض السكان في بلدة جباليا لغاز الرادون .في هذه الدراسة تم قياس معدل انبعاث الرادون من بعض مواد البناء المقصوفة المتعارف على استخدامها في بلدة جباليا . وذلك باستخدام وباستخدام تقنية (CR-39) كواشف الحالة الصلبة للمسارات النووية المعروفة تجاريا باسم الأوعية المغلقة .بعد تعرض الكواشف لغاز الرادون المنبعث من العينات لمدة 124 يوم ,تم تظهيرها كيميائيا باستخدام محلول هيدروكسيد الصوديوم بتركيز 6N لمدة 260دقيقة ثم تم حساب متوسط عدد المسارات في وحدة المساحة باستخدام مجهر ضوئي والتي استخدمت لحساب كل من معدل انبعاث غاز الرادون وتركيزه والجرعة المكافئة السنوية الناتجة عن كل من عينات مواد البناء المقصوفة. تشير النتائج التي تم الحصول عليها من الدراسة الحالية إلى أن معدل انبعاث غاز الرادون من عينات الباطون والاسبست ذات قيم مرتفعة نسبيا بالمقارنة مع غيرها من مواد البناء يليها – على الترتيب -كل من البلاط واحجار البناء والطوب الاحمر والسراميك والرخام، بينما وجدت مساهمة أقل من الزجاج في تركيز غاز الرادون .تم مقارنة الجرعة السنوية الفعالة لكل عينة مع حدود الجرعة الفعالة الموصى بها من قبل المجلس الوطني للقياسات الاشعاعية وجد أن الجرعات المكافئة الناتجة عن عينات مواد البناء المستخدمة منخفضة إلى ما دون الحدود العليا للقيم العالمية باستثناء تلك الناتجة عن الباطون والاسبست. النتائج قريبة لنتائج سابقة من دول أخري مع فروقات ترجع الي مصادر مواد البناء من دول مختلفة، وان الدراسة تحتاج إلي المزيد من الاجهزة المتقدمة لمعرفة المحتوي لمواد البناء من المواد المشعة كاليورانيوم وغيره.