Faculty of Graduate Studies

Chemistry Department

Measurement of Natural Radioactive Isotopes Concentration in Soil Samples in the Northern Part of West Bank - Palestine

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DEDICATION

I dedicate this work to my beloved parents Jamal Yousef and Nofouz Hassan, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional, and financial support.

To the great mother of my dear husband Nisreen Abu Sharar.

To my brother Adham and sisters roses of my life Azhar, Afnan, Adan and Asayel.

To my children are the light of my life Yafa, Bara, and Marya

Dedication to my dear university, Hebron University

To my teachers and colleagues in the Department of Chemistry

To my wonderful homeland, beloved Palestine.

DECLARATION

I certify that this thesis submitted for the degree of a master is the result of My own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other University or Institution.

Name: Rounz Jamal Yosef Shawamreh

Signed

Date: 16 / 6 / 2021

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In the name of Allah, the Most Beneficent, the Most Merciful. All praise be to Allah, the Almighty, the Glorious who has bestowed upon us.

I am deeply grateful to my supervisor Prof.Dr.Khalil Thabayneh guidance, enlightening, support, and well supervising. I consider myself very lucky for being able to work with a very considerate and encouraging professor.

My dear husband Mohammad Rasem Abu Sharar thanks for all the great things that you always give me. for your continued support. thanks for your sacrifices for me and my children. I'm proud of you and I promise to be with you until you reach what you aspire to. I presented to you all my love and appreciation.

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LIST OF ABBREVIATIONS

X-rays : "Unknown", rays .

RF: RadioFrequency .

ELF: Extremely Low Frequency .

MW: MicroWave .

IR: InfraRed

UVA: UltraViolet has a longer wavelength, and is associated with skin aging

UVB: UltraViolet has a shorter wavelength and is associated with skin burning.

nm: nanometer

km: kilometer

KHz: Kilohertz

THz: Terahertz

IARC: International Agency for Research on Cancer

***α*:** alpha

***β*:** Beta particles

β-: negative beta decay

β+ : positive beta decay

***γ*:** Gamma-ray

^{238}U: Uranium-238

^{235}U: Uranium- 235

^{232}Th: Thorium-232

^{40}K: potassium-40

***A (t)*:** Activity, the number of nuclei decaying per second

***N*:** Number of radioactive nuclei

***λ*:** decay constant.

***N_0*:** Number of atoms at time equal to zero

***N(t)*:** Number of atoms at any different time

$T_{1/2}$: Half-life

t_{av}: average lifetime

SI unit: International System Of Units

***Bq*:** Becquerel

***Ci*:** Curie

MeV: MelionelectronVolt

Rad: Radiation absorbed dose

Gy: Gray

Rem: Roentgen equivalent man

Sv: Sievert

Dps: Disintegrations per second

X: Exposure

D: absorbed dose

D_E: Dose Equivalent

RBE: Relative Biological Effectiveness

E: Effective dose

W_T: Tissue Weighting factor

mSv: millisievert

WHO: World Health Organization

SSNTD: Solid-State Nuclear Track Detector

NMP: Northern Malaysian Peninsula

DNA: Deoxyribonucleic Acid

CR-85: Columbia Resins No.85 Laser Radar Detector

CR-115: Columbia Resins No.115 Plastic track detector

CR-39: Columbia Resin No. 39 Plastic Nuclear Track Detector.

NaOH: Sodium Hydroxide

E_A: Surface radon exhalation rate

E_M: Mass radon exhalation rate

C_S: The Dissolved radon concentration

AED_{in}: Annual Effective Dose for indoors

AED_{out}: Annual Effective Dose for outdoors

AED_{tot}: total Annual Effective Dose

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

OECD: Organization for Economic Cooperation and Development

TSS: Tulkarm Soil Sampels

JSS: Jenin Soil Sampels

TUSS: Tubas Soil Sampels

Abstract

In this study, solid-state nuclear track detectors (CR-39) were used for measurement of radon concentration and annual effective dose by register alpha-emitting radon Rn^{222} in soil samples collected from different sites in the northern parts of West Bank- Palestine. A total of 40 soil samples were collected from Tulkarm, Jenin, and Tubas Governorates.

The total average values of radon concentration for Tulkarm, Jenin, and Tubas governorates were 505.2, 528.0, and 515.3 Bq/m^3, respectively. These results indicate a risk to public health due to these high concentrations.

The total average value of the annual effective dose for these governorates is 17.5, 18.3, and 17.8 $mSvy^{-1}$, respectively. The values are found to be slightly larger than the action levels (3-10 $mSvy^{-1}$) recommended by ICRP- 1993. The measurements taken in this study represent a baseline database of activity levels that can serve as a reference point for future studies to indicate impacts from future events.

قياس تراكيز النظائر المشعة الطبيعية في عينات من التربة في الجزء الشمالي من الضفة الغربية ـ فلسطين

اعداد: رونز جمال يوسف شوامرة

اشراف: أ. د. خليل ذباينه

الملخص

في هذه الدراسة ، تم قياس تركيز الرادون والجرعة الفعالة السنوية عن طريق قياس الرادون لباعثات ألفا باستخدام كواشف الأثر النووي للحالة الصلبة للمسارات النوويه SSNTDS نوع (CR-39) ما يسمى تجاريا بمقاييس جرعات تقنية الاوعية المغلقه . تم جمع ٤٠ عينة تربة من مواقع مختلفة من محافظات طولكرم ، جنين وطوباس في شمال الضفة الغربية- فلسطين.

بلغ متوسط قيم تراكيز غاز الرادون لمحافظات طولكرم ، جنين وطوباس: ٥٠٥,٢ ، ٥٢٨,٠ ، ٥١٥,٣ بيكريل /م^{٣} على التوالي. تشير هذه النتائج إلى وجود خطر على الصحة العامة بسبب هذه التركيزات العالية. بلغ متوسط القيمة الإجمالية للجرعة الفعالة السنوية لمحافظات طولكرم ، جنين وطوباس: ١٧,٥ ، ١٨,٣ ، ١٧,٨ملي سفيري/سنة على التوالي . وقد تبين أن القيم أكبر قليلاً من مستويات العمل ($3\text{-}10\ mSvy^{-1}$) التي أوصت بها ICRP- 1993 . تظهر النتائج الحالية أن تركيز الرادون والجرعات الناتجة في جميع عينات التربة أعلى من الحد المسموح به من ICRP. تمثل القياسات المأخوذة في هذه الدراسة قاعدة بيانات أساسية لمستويات النشاط التي يمكن أن تكون بمثابة نقطة مرجعية للدراسات المستقبلية للإشارة إلى التأثيرات من الأحداث المستقبلية.

CHAPTER ONE

INTRODUCTION

Chapter 1- Introduction

1.1. Introduction

In 1895, Wilhelm Roentgen, discovered X-rays while he was testing whether cathode rays could pass through glass. His cathode tube was covered in black screen, so he was surprised when a bright light though escaped and projected onto a nearby fluorescent screen. Through the process, he found that the obscure light would pass through most substances but leave shadows of solid objects. Because he did not know what the rays were, he called them "X", meaning "unknown", rays. In 1896 Henri Becquerel was using naturally fluorescent minerals to study the properties of x-rays, which had been discovered in 1895 by Wilhelm Roentgen. He exposed potassium uranyl sulfate to sunlight and then placed it on photographic plates covered in black paper, believing that the uranium absorbed the sun's energy and then emitted it as x-rays[1]. But his experience "failed" because it was overcast in Paris and this theory was disproved. Becquerel chose, for some reason, to create his photographic plates. The photos were solid and clear to his surprise, which revealed the uranium radiation emitted without an external energy source, such as the sun. Radioactivity was discovered by Becquerel. Marie Curie, who started researching the newly discovered phenomenon with her husband, Pierre, coined the term radioactivity. The Curie removed uranium and found that the remaining ore showed more activity than pure uranium to their surprise. They believed that other radioactive elements were in the ore. The elements polonium and radium were discovered. For another four years, tons of minerals have been processed to separate each element enough to find its chemical properties. Ernest Rutherford, who has performed several experiments to research and show the characteristic features of radioactive decay, called these alpha, beta, and gamma particles [1,2].

1.2. Types of Radiation

Radiation can be either non-ionizing or ionizing, contingent upon how it influences matter

1.2.1. Non-Ionizing Radiation

Non-ionizing radiation stores energy in the materials through which it passes, but it does not have enough energy to break molecular bonds or remove electrons from atoms. Non-ionizing radiation includes the spectrum of radio frequency (RF), and extremely low

frequency (ELF), microwave (MW), infrared (IR), visible light, and ultraviolet (UVA and UVB). Lasers commonly use in the IR, visible, and UV frequencies.

Non-ionizing radiation is electromagnetic radiation with a wavelength between 200 nm and up to 3 km, which equates to a frequency range between about less than 100 kHz to 1000 THz [3].

Different biological impacts are observed for different kinds of non-ionizing radiation. The International Agency for Research on Cancer (IARC) recently announced that there could be some risk from non-ionizing radiation to humans. But another study reported that the basis of the IARC evaluation was not regular with observed incidence tendencies. This and other reports suggest that there is practically no way that results on which the IARC based its conclusions are correct [4, 5].

1.2.2 Ionizing Radiation

Ionization is the mechanism by which an electron receives enough energy to disconnect itself from an atom. This mechanism contributes to the creation of two particles or ions: the positive-charge molecule and the negative-charge free electron.

The energy emitted from natural or artificial sources is ionizing radiation. Their energy is greater than non-ionizing radiation, necessary to bring about chemical changes by breaking chemical bonds. It possesses the power to strip electrons from an atom or to decay the nucleus of the atom in the event of extremely high-energy radiation. Each ionization releases energy which is absorbed by the ionized atomic material [6].
There are several types of ionizing radiation:

(i) Alpha particles

The composite particles of the alpha (α) are closely bound together with two protons and two neutrons. During a radioactive decay called alpha decay, they are released from the nucleus of certain radionuclides. An alpha particle is similar to the nucleus of a typical helium atom (atomic mass 4), a twice ionized helium atom. The first radioactive radiation was detected, beta particles and gamma-rays were easily identified. alpha particles (also known as alpha radiation or alpha-rays). In contrast with other nuclear types of radiation, alpha particles are comparatively sluggish and heavy[7]. Alpha particles cannot penetrate matter very far because they are extremely ionizing and are rested by a few centimeters of

air or less than a tenth of millimeters of biological tissue. In a very limited distance, they can cause some ionization. This allows them to damage the same amount of deposited energy much more biologically [7].

(ii) Beta particles

Beta particles (β) are high-energy, high-speed thrown out of the nuclear by certain radionuclides in the process of radioactive decay known as beta-decay. Beta decay usually occurs in nuclei that are too stable for neutrons.

Beta particles bear either the negative charge (electron, β-) or positive charge (positron, β+). Their light mass means that, by contact with matter, they lose energy easily and have a risk-taking direction as they pass by air or other materials. Beta particles are much less ionized than alpha particles; for a certain amount of energy deposition, they typically have less damage. They generally have the range of tens of centimeters in air and some millimeters in materials. Beta-particulate matter can move several centimeters, or even meters of air, through millimeters of skin or tissues and be less ionized than alpha-particle materials. Enough beta-radiation strength can lead to burns, including serious sunburn. Inhaling or ingesting beta-emitting radionuclides may harm internal cells and organisms [7].

(iii) Gamma radiation

Gamma-ray (γ) is a radioactive decline-emitting electromagnetic energy packet, emitted by the nucleus of certain radionuclides. The most energized photons in the electromagnetic spectrum are gamma photons. Every photon has a certain measured (or bundle) of energy and these photons are all electromagnetic radiation. Gamma-ray photons have the highest energy in the EMR spectrum and the shortest wavelength of their waves, Gamma rays are powered by many types of materials, including the tissues of the human being. Quite dense materials, such as lead, typically protect gamma rays slowly or avoid them. High exposures can cause direct acute effects by immediate damage to cells, similar to all exposures to ionizing radiation. Low exposure levels contribute to a stochastic health risk, with an increased risk of cancer induction [7].

1.3. Sources of Ionizing Radiation

Natural and artificial sources of radioactivity are present in our environment. They are many and assorted and some are also dangerous.

1.3.1. Natural Sources

This widespread natural radiation is primarily derived from natural sources, almost anywhere in the environment. Natural radiation has three primary sources: cosmic radiation, earth radiation, and internal radiation [7].

(i) Cosmic radiation

Cosmic radiation constantly celebrates the Earth's external atmosphere. Usually, the sun and other celestial phenomena in the universe come from many sources. A certain amount of ionizing radiation penetrates the atmosphere of the earth and is absorbed by humans, resulting in natural radiation. The exposure levels of regions at higher altitudes in an aircraft increase. These factors can increase a human being's total amount of radiation for his lifetime [7,8].

(ii) Terrestrial radiation

The composition of the earth's crust is an important source of natural radiation from terrestrial radiation. Natural deposits of ^{238}U, ^{235}U, ^{232}Th, and ^{40}K which release small quantities of ionizing radiation in the process of natural decay are the main contributors. Mostly all over uranium and thorium can be found. Traces of these minerals can also be used in construction materials so that they can be exposed to both indoor and outdoor natural radiation [7,8].

Radon is a toxic gas that occurs naturally in minute quantities as an intermediate step in the normal radioactive decay chains through which thorium and uranium and can cause lung cancer. Inert, colorless, odorless, radon gas. Radon is, of course, in small quantities in the atmosphere. Radon is easily spread outside and is not a health concern in general. In households, schools, and offices, most radon exposure occurs. After it reaches buildings through cracks and other foundation troughs, the radon gas is captured indoors. With validated cost-effective strategies, indoor radon can be monitored and handled [9].

(iii) Internal Radiation

All people have internal radiation inside their body from birth and are thus sources for exposure to others, primarily radioactive potassium 40 and carbon-14. Dose differences between people are not as large as those associated with celestial and terrestrial sources [7].

1.3.2. Artificial Radiation Sources

In addition to natural background radiation, people are exposed to radiation from various artificial sources, the largest of the application of X-rays in medical diagnosis. Other examples of human radiation sources for members of the public include nuclear power stations, coal-fired power stations, smoke detectors, TV sets, Radium watches, and various other consumer products; radioactive fallout from nuclear weapons and radiation released in nuclear power production [7,8].

1.4. Radioactive decay

The spontaneous decay of the atomic nucleus due to energy and matter being emitted from the nucleus is radioactive decay. Know, there are unstable nuclei in a radioisotope with insufficient binding energy to keep the nucleus together. Radioisotopes want to be stable isotopes because they shift to stabilize continuously. In the process, energy and matter are released from your nucleus and sometimes become a new element. The process known as transmutation is the transformation of one entity into another as a result of nucleus changes. The radioactive degradation and transmutation shall be continued until a new, stable, and non-radioactive element is formed. Naturally or artificially, transmutation can occur [10].

1.4.1. Radioactive decay

There is a spontaneous radioactive decay and no physical or chemical influences Temperature, pressure, or combination of reactions.[11,12]

The basic law of radioactive decay can be given by:

$$A(t) = \frac{dN(t)}{dt} = \lambda N(t) \qquad 1.1$$

where *A (t)* is the activity (i.e. The number of nuclei decaying per unit time),

N is the number of radioactive nuclei, λ is the disintegration or decay constant.

By integrating the equation (1.1) concerning (N_0) which represents the number of atoms at time equal to zero and *N(t)* represents the number of atoms at any different time:

$$\int_{N0}^{N(t)} \frac{dN}{N} = -\lambda \int_{0}^{t} dt \qquad 1.2$$

Can be written (1.2) as :

$$N(t)= N_0 e^{-\lambda t} \qquad 1.3$$

or

$$\ln N(t)-\ln N_0= -\lambda t \qquad 1.4$$

Referring to equation 1.4 can be written as:

$$A(t)= A_0 e^{-\lambda t} \qquad 1.5$$

1.4.2. Half-life and mean lifetime

Half-life ($T_{1/2}$) is the time taken in a pure sample to decay for half of the stable particles. The time needed to halve a sample's operation also [11,12]:

$$T_{1/2}=\ln 2/\lambda=0.693/\lambda \qquad 1.6$$

The expectation value of the time needed for an initial population of N_0 radioactive nuclei to decay to 1/e of their original number is called the mean life (average life):

The relation between average lifetime and a half-life is [11,12]:

$$t_{av}= 1/\lambda \qquad 1.7$$

$$t_{av}=1/\lambda=T_{1/2}/0.693=1.44T_{1/2} \qquad 1.8$$

1.4.3 Activity

Activity, in radioactive-decay processes, the number of disintegrations per second, or the number of unstable atomic nuclei that decay per second in a given sample. The SI unit is Becquerel (*Bq*) or curie (*Ci*), where 1 *Ci* is equal to 3.7×10^{10} *Bq*.

Nuclear decay is a random process: when a certain unstable nucleus decreases, we cannot predict precisely. However, the chances of a nucleus deteriorating in a certain time can be determined. The product λN is the activity and written as [11,12]:

$$A=\lambda N=\lambda N_0 e^{-\lambda t} \qquad 1.9$$

1.4.4. Radioactive equilibrium

The radioactive balance occurs when a radioactive nuclide falls at the same rate it is made. The disintegrating nucleus is typically called the parent and, after this case, the nucleus of the daughter [13].

$$\lambda_1 N_1=\lambda_2 N_2 \qquad 1.10$$

When a half-life of the parent nucleus is short of the half-life of the daughter's nucleus, radioactive equilibrium is not defined. In this case, some members of the decay chain cannot have a production rate and decay rate equal. There is no equilibrium in the process.

1.5. Natural Decay Chains

1.5.1. ^{238}U decay series

The (4n+2) chain of uranium-238 is called the "Uranium-series" or "Radium series". This sequence contains the following ingredients: astatine, bismuth, plum, polonium, protactinium, radium, radon, thallium, thorium, beginning with naturally occurring uranium-238 ($T_{½} = 4.5\times10^9$ years). Any sample, whether metal, compound, or mineral, is present at least temporarily. Lead-206 (Stable) finishes the sequence. Complete energy, including energy lost to neutrinos, from Uranium -238 to Lead- 206, is 51,7 meV [14,15].

1.5.2 ^{232}Th - Decay Series

The (4n) chain of Th-232 is sometimes referred to as the "Thorium Series". The following elements of this sequence are included: actinium, bismuth, plum, polonium, radium, and thallium, beginning at naturally occurring Thorium-232 ($T_{½}$ = 1.4×10^{10} year. All are present in every natural thorium, whether metal, compound, or mineral sample, at least temporarily. Lead-208 (Stable) is the finishing touch.

Total Thorium-232 energy, including energy loss to neutrinos, released from lead-208 is 42.6 MeV [14].

1.5.3 Actinium -Decay Series

The (4n+3) chain of Uranium-235 chains is generally called "Series of Actinium" or "Cascades of Actinium." The following components of this decay sequence start with natural isotope U-235 ($T_{½}$ = 7×10^{8} years). Actinium, astatine, bismuth, francium, lead, polonium, rhythm, thallium, radium. Any sample containing Uranium-235, whether metal, compound, or mineral, is present at least temporarily. The stable isotope Lead-207 (Stable) ends this cycle. Total energy, including energy lost by neutrinos, from Uranium-235 to Lead-207 was 46.4 MeV [14].

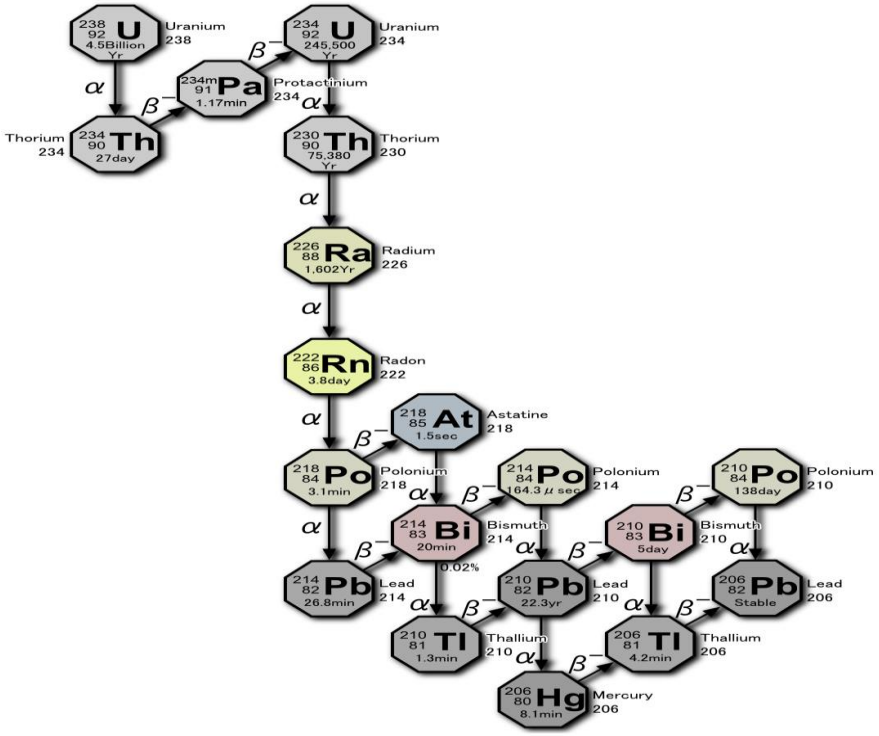


Figure 1.1: The ^{238}U decay series [14]

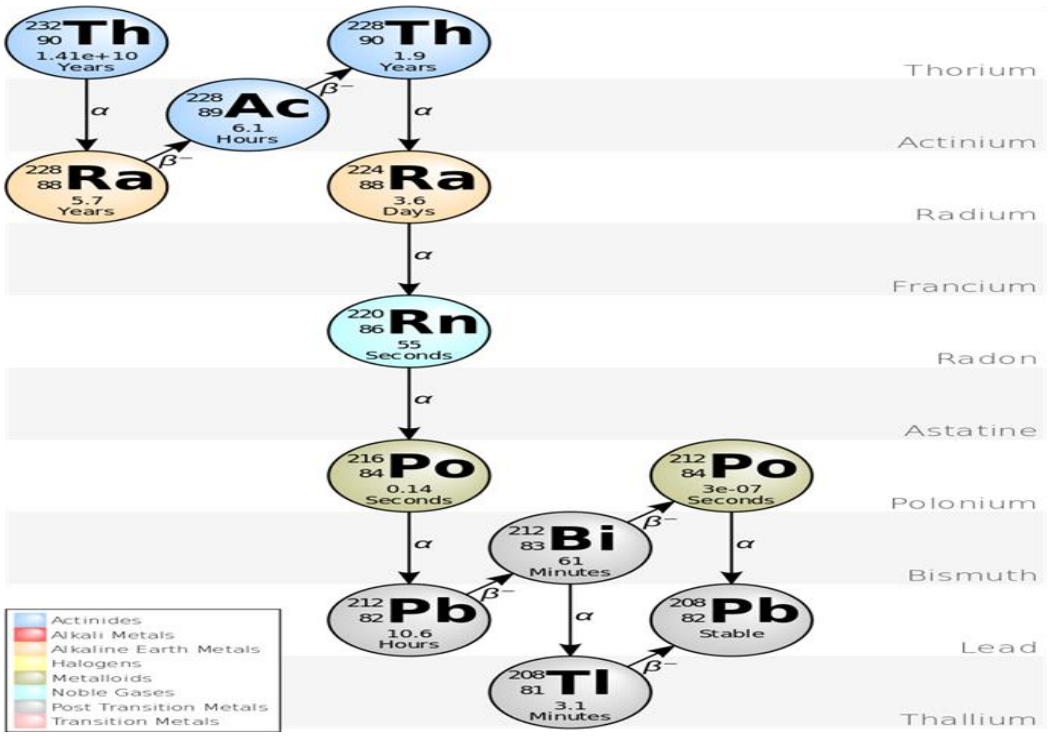


Figure 1.2: The ^{232}Th - Decay Series[14]

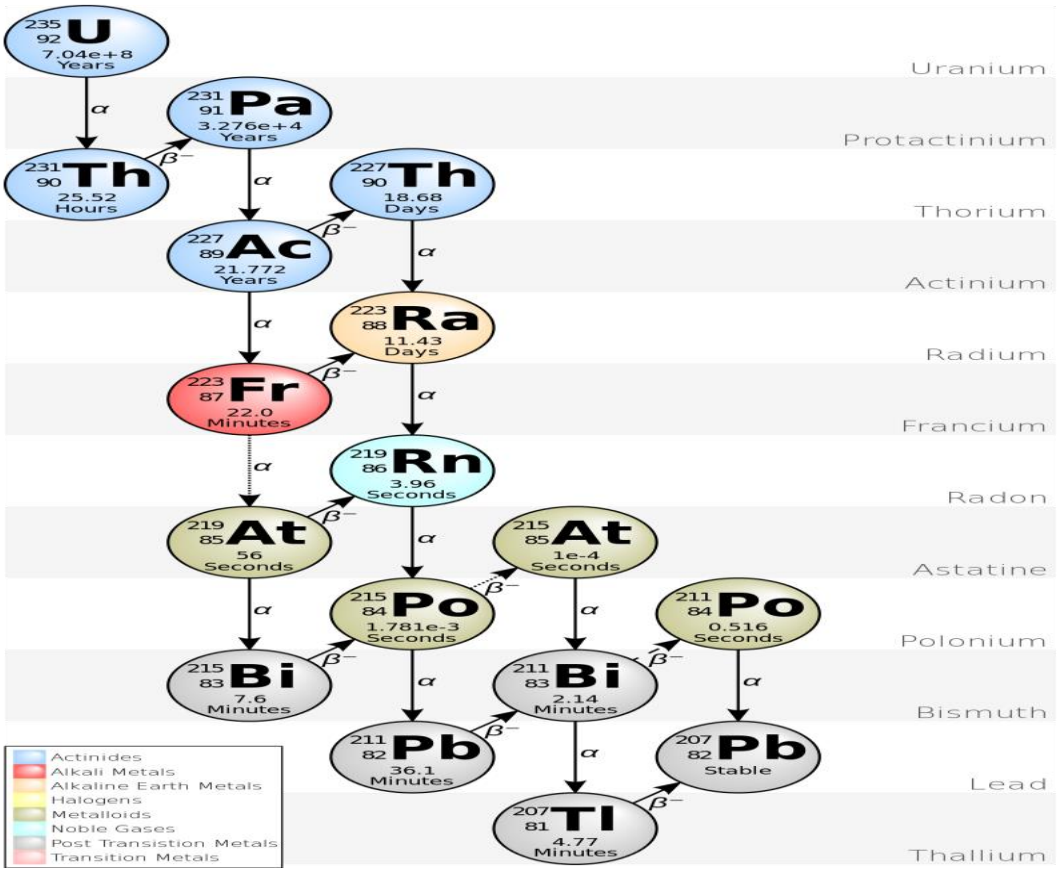


Figure 1.3: The Actinium -Decay Series [14]

1.6. Units of Radiation

1.6.1. Radiation absorbed dose (Rad)

The radiation-absorbed dose (rad) is the amount of energy from any type of ionizing radiation deposited in any medium (e.g., soil, air, water, tissue ..). One rad means that one gram of material absorbed 100 ergs of energy as a result of radiation exposure. The related SI unit is the gray (Gy), where one Gy is equivalent to 100 rad. For more information. The unit rad can be used for all types of radiation of various radiations due to the radiation type *Q* weighing factor [15].

$$1\ rad = 100\ erg/gram$$

1.6.2. Roentgen equivalent man (Rem)

A unit of equivalent absorbed dose of radiation which takes into consideration the relative biological efficacy or variations in the transfer to human tissue of various sources of ionizing radiation The dose in rem refers to the dose. In rad, the consistency factor is multiplied (*Q*). The efficiency factor for beta and gamma radiation is taken as one, i.e. rem is equivalent to rad. The efficiency factor for alpha radiation is 20, which is 20 times more rad. Rem is a test of the harm to the body. For neutrons, *Q* normally is considered to be 10. The relation between *rem* and *rad* is [15]:

$$rem = rad \times Q$$

1.6.3. Gray (Gy)

It deposits energy when ionizing radiation pierces the human body or object. The energy absorbed by radiation exposure is known as the absorbed dose. A gray (Gy) unit is used to measure the absorbed dose. One gray equals an energy unit (joule) in a kilogram of a substance. A radiation unit of 100 rad is absorbed. The relation between *Gy* and *rad* is [15]:

$$1\ Gy = 100\ rad = 1\ joule/kg$$

1.6.4. Sievert (Sv)

A unit of equivalent absorbed dose equal to 100 rem, [16]

where

$$1\ Sv = 100\ rem$$

$$Sv = Gy \times Q$$

1.6.5. Curie (Ci)

The traditional unit of radioactivity, which measures the number of decays per second, equal to the radioactivity of one gram of pure radium-226.[16]

$$1\ Ci = 37\ billion\ dps = 37\ billion\ Bq$$

1.6.6. Becquerel (Bq)

The standard international unit of radioactivity equal to one disintegration per second [16]

$$1\ Bq = 37\ PCI$$

1.6.7. Disintegrations per second (dps)

The number of subatomic particles (e.g. alpha particles) or photons (gamma rays) released from the nucleus of a given atom over one second. One dps = 60 *dpm* (disintegrations per minute).[16]

$$1\ dps = 1\ Bq$$

1.7. Radiation doses

1.7.1. Exposure (X)

Exposure unit is defined as the amount of x-ray or γ-radiation that produces ions with a charge of a coulomb per kilogram of air in the air. It does not have a special name, and is being called an "*X* unit."

$$X = dQ/dm\ (C/kg\ air) \qquad (1.11)$$

The use of the exposure unit is limited to X-ray or γ - rays whose quantum energies do not exceed 3 MeV[16].

Radiation exposure (X): is a measure of the amount of ionization produced in 1 cm^3 (of air) by gamma or x-rays.

If one ionic charge 1e ~ 4.8×10^{-10} esu (1 esu = 1 stat Coulomb) then, how many e -ions in 1 esu/cm^3 ~ 2.08×10^9 e -ions/cm^3.

The unit of exposure was named Roentgen (R), where,

$$1R = 1\ esu / cm^3\ STP\ air\ (Old\ unit)$$

The strength of an X-ray or gamma-ray field is usually expressed as an exposure rate, such as coulombs per kilogram per hour.

$$1R = 2.58 \times 10^{-4}\ Coulomb / kg\ air.\ (SI\ New\ unit)$$

When exposure is measured in roentgens (common unit), X-ray or γ-ray field strength (exposure rate) is measured in units such as R/min or mR/hr. roentgens per unit of time [15].

In air: 1 R = 0.0087 J/kg = 0.0087 Gy = 0.87 rad

In human body: 1 R = 0.96 rad = 0.96 rem

$$R \sim 1\ rad \sim 1\ rem$$

1.7.2. The absorbed dose (D)

Absorbed dose is an essential term because the effect of radiation on biological tissue depends directly on the amount of energy absorbed by that tissue. The gray (Gy) dose unit of SI is absorbed. 1 gray is equal to 1 joule of energy supplied to 1 kg of matter. An older dose unit is the rad [15].

$$D = U/m\ \ (J/kg\ or\ Gy) \qquad (1.12)$$

Where 1Gy = 1 J kg^{-1} = 100 rad

1.7.3. The dose equivalent (D_E)

The dose equivalent can be thought of as an expression of the dose in terms of its biological effect. To estimate this, we define the relative biological effectiveness (RBE) of a particular kind of radiation (also known as the Quality Factor, *Q*).A measure of the

biological damage caused by radioactive exposure to living tissue. The dose equivalent, often known as a "biological dose," is measured by multiplying the consistency factor as the consequence of the absorbed dose in a tissue and then also multiplying the other required changes at the site of interest [16].

RBE (Q): is a weighting factor that depends on the type of ionizing radiation. The Q is higher for radiation types that deliver their energy to a smaller number of cells.

Table 1.1 : Approximate *Q* values (summarized from ICRP (1991) [17]

Radiation	*Q*	Radiation	*Q*
Beta, X and γ rays	1	Protons	5
Electrons	1	Heavy and recoil nuclei, Alpha Particles	20
Thermal Neutrons	3	Slow neutrons and fast neutrons	5, 20

The dose equivalent is measured in Sievert (Sv). The dose equivalent is obtained by multiplying the absorbed dose by the *Q* is:

$$D_E(Sv) = D\ (Gy) \times Q \qquad (1.13)$$

The non-SI unit still in use is the rem (which stands for Röentgen equivalent man)

$$D_E(rem) = D\ (rad) \times Q \qquad (1.14)$$

where 1 Sv = 100 rem

1.7.4. The Effective dose (E)

The "effective dose" is a biological dose widely used to protect radiation, since it decides whether the radiation exposure of a person is harmful. The nature of the incoming radiation, and the sensitivity of the affected corporeal parts, are taken into account. The 'effective dose' unit shall be the sievert, the unit used by a local organ, gland, or some other part of the body to consume the equivalent amount of dose [18].

$$E = \sum D_E \times W_T \qquad (1.15)$$

Where E is the effective dose to the entire organism, D_E the equivalent dose absorbed by tissue and W_T is the tissue weighting factor

1.8. The Health Effects of Ionizing Radiation

Tissue and/or organ irradiation damage depends on the radiation exposure obtained or on the dose taken in a quantity called the gray (Gy). The potential harm caused by the doses that are ingested depends on the radiation type and tissue and organ sensitivity.

Radiation can affect tissue and/or organ function above certain thresholds and cause acute symptoms such as redness of the skin, hair loss, radiation burns, or acute radiation syndrome. At higher levels and higher dosage doses, these effects are more severe. For example, the dose threshold is around 1 Sv (1000 mSv) for acute radiation syndrome.[19]

The risk is slightly smaller if the radiation dose is low, so it is likely to heal the harm more likely. There is still a chance of long-term effects like cancer, but years or even decades later could be present. Such results won't always occur, however, their chances of radiation dose are proportional to the quantity. There is a greater risk of radiation exposure for children and teenagers than adults and here lies the danger.[19]

A significant rise in the cancer risk in doses greater than 100 mSv has been seen in epidemiological research in populations exposed to radiation, such as nuclear bomb survivors or radiotherapy patients. More recently, some epidemiological studies have indicated that cancer risk can increase even at lower doses (between 50-100 mSv) in people exposed to health exposures during childhood (pediatric CT).[19]

The brain damage in fetuses following an acute dose above 100 mSv can be caused by prenatal exposure to ionizing radiation between weeks 8-15 and 200 mSv between weeks 16-25 of pregnancy. Human research did not show radiation risk to the fetal brain before week 8 or after week 25 pregnancy research. The risk of cancer following prenatal radiation exposure is like the risk after early childhood exposure in epidemiological studies [19].

1.9. Literature Review

1.9.1. Local Studies

There are many studies for measurements of radon concentration levels in Palestine.

Thabayneh K. M. (2013), measuring the concentration levels and exhalation rate of ^{222}Rn in natural radionuclides in different imported granite types used in Palestinian dwellings by using CR-39 detectors. The radon exhalation rate values range between 3.9 and 30.6 Bqm^{-1} day^{-1}. The effective radium content was found to vary from 0.81 to 6.12 with an overall average value of 3.1 Bq kg^{-1}. In conclusion, granite is one of the main sources of radionuclides and radon exhalation in buildings [20].

Thabayneh K. M. (2016), measuring the radon concentration and the exhalation rates of soil samples collected from different sites in Hebron sites - Palestine by using the sealed-can technique has CR-39 detectors. The total average values of radon concentrations for 0, 20, 40, and 60 cm depths were 294, 357, 433, and 512 Bqm^{-3}, respectively. The data showed an increase in radon concentration levels with depth. The values were found to be within the safe limits as recommended by *ICRP* and *WHO*. The results showed that the area under investigation is safe from the health hazard site of view as far as the radon is concerned [21].

Thabayneh K. M. (2018), using the sealed can technique dosimeters to measurements the radon concentrations and radon exhalation rates in soil samples collected from different regions in Bethlehem governorates Palestine. The radon concentrations varied from 19.1 Bqm^{-3} to 572.9 Bqm^{-3} with an average value of 145.0 Bqm^{-3}. The radon exhalation rate in these samples also varied from 6.9 $mBqm^{-2}$ h^{-1} (0.26 $mBqkg^{-1}$ h^{-1}) to 207.2 $mBqm^{-2}$ h^{-1} (7.84 $mBqkg^{-1}$ h^{-1}) with a total average value of 52.2 $mBqm^{-2}$ h^{-1} (1.97 $mBqkg^{-1}$ h^{-1}). All values of radium content are under test were found to be lower than the corresponding global value 30 $Bqkg^{-1}$. The results show that the radon concentration and the resulting doses in all samples are below the allowed limit from ICRP. The radiological health of the population that may result from these doses is found to be low [22].

Walid Khalilia et al. (2020), measuring the radon concentration, exhalation rates, radium contents, and radiation exposure in soil samples collected from different sites in the governorate of Jericho- Palestine, by using the sealed-can technique. The concentration of radon levels in the study samples ranges from 169.3 to 6184.4 Bqm^{-3} with a total average value of 1388.0 Bqm^{-3}. The effective radium content values were found to range from 8.2 to 301.2 $Bqkg^{-1}$with a total average value of 68 $Bqkg^{-1}$. The average radon exhalation rate in these soil samples are varied from 73.2 $mBqm^{-2}\ h^{-1}$ (3.1 $mBqkg^{-1}\ h^{-1}$) to 1419.8 $mBqm^{-2}\ h^{-1}$ (54.7 $mBqkg^{-1}\ h^{-1}$) with a total average value of 500.0 $mBqm^{-2}\ h^{-1}$ (19.0 $mBqkg^{-1}\ h^{-1}$). A good correlation was also found between the effective radium content and the radon exhalation rate of soil samples. For this reason, the area from which the samples were collected is not safe for agriculture and housing construction as it poses a major health risk to humans. Thus, the obtained results are important to know if there is any harmful radiation, and it can be used as reference information to estimate any changes in the radiation level in the Jericho district environment [23].

M. El-Ghossain et al (2006), detecting the alpha particles radiation contents of soil samples using solid-state nuclear track detector (SSNTD) CR-39, collected from Nusirate area in Gaza-Strip. Results showed that the activity of Alpha particles in soil has a maximum value of 9.305 Bqm^{-3}, and least 2.878 Bqm^{-3}, with an average value of 5.244 Bq m^{-3}. The results showed that there is a variation in the values of alpha particles measurements which is due to the type of soil, uranium and radium contents, the rock distribution, and industrial activities [24].

F. Shoqwara et al., (2013), calculated the radon exhalation rate in different building materials used in construction in the Nablus district by using the closed-can technique contains CR-39 detector. Results show that the radon exhalation rates from granite and marble have relatively high values as compared to other building materials. The radon exhalation rate ranges from 55.4 mBq/m^2h for gypsum samples to 589.5 mBq/m^2h for granite samples, with a total average value of 268.56 mBq/m^2h. The radon concentration, the effective radium content, and the annual effective dose average values were 148.5 Bq/m^3, 1.93 Bq/Kg, and 3.74 mSv/y, respectively. The radon exhalation rate from the studying samples is low and under the global value except for granite, marble, and some cement samples, and thus except for the excluded, the studied materials are safe as construction materials [25].

1.9.2. International Studies

Abd- Elmoniem A. Elzain (2015), measurements and calculated the radium concentration, radon surface rate, and mass exhalation rate for 168 soil samples collected from some cities of Gezira state in Sudan. In this study, the can technique dosimeter containing CR-39 is used to estimate the radium concentration and radon exhalation rates from the soils of El-Hosh, El-Managil, and Medani towns in the Gezira State- Central Sudan. The results of radium concentrations**,** mass exhalation rate and surface exhalation rate were found to be 91.0 $Bqkg^{-1}$, 0.10 Bq $kg^{-2}h^{-1}$ and 4.86 Bq m^{-2} h^{-1} for El-Hosh soils, 182 $Bqkg^{-1}$, 0.20 Bq $kg^{-2}h^{-1}$ and 9.77 Bq $m^{-2}h^{-1}$ for El-Managil soils and 249 $Bqkg^{-1}$, 0.27 Bq $kg^{-2}h^{-1}$ and 13.35 Bq $m^{-2}h^{-1}$ for Medani soils. All the values of radium concentration in soil samples for this study were to be lower than the permissible value of 370 $Bqkg^{-1}$ recommended by OECD and larger than the average global value of 30 $Bqkg^{-1}$ [26].

Hesham A. Youssef et al., (2015), estimated the radon concentration and exhalation rate from 30 surface soil in different locations of Graduate's Villages West Nile Delta, Egypt. The radon concentrations and radon exhalation rate were measured by using the can technique with a CR-39 detector. The average values of radon concentrations ranged from 236.3 to 717. 8 Bqm^{-3} and the area exhalation rate from 0.28 to0.86 Bq $m^{-2}h^{-1}$. These results are being used as reference information to assess any changes in the radiation background level due to geological processes in the investigated area [27].

E. Tabar et al., (2013), measurement the radon concentration in soil samples collected from a geothermal area located in the Dikili region, Turkey. The radon concentration were determined by using the LR-115 Solid State Nuclear Track Detectors (SSNTD). The radon concentration of soil samples ranged from 98-8594 Bqm^{-3} with an average value of 1920 Bqm^{-3}**.** The highest radon concentration was observed in summer and the lowest concentration was measured in winter. The calculated dose values do not exceed the radioprotection standards suggested by international agencies [28].

B.A. Almayahi et al., (2012), determined the radon concentrations in soil samples collected from the Northern Malaysian Peninsula (NMP) using the SNC continuous radon

monitor (model 1029). The radon concentrations range from 7–64 Bqm^{-3} with an average value of 20 Bqm^{-3}. A positive correlation (R= 0.81) was observed between the ^{222}Rn and ^{226}Ra concentrations in soil samples. This work has established baseline information on the natural radioactivity status of NMP, which will serve as a reference for future studies [29].

Y. M. Abbas et al., (2020), measurement the radon concentrations, radium contents, radon surface exhalation rate, and mass exhalation rate, in rock samples in the Al-Qusair area, Egypt, by using CR-39 solid-state detector, to estimate these quantities. The measured radon concentration in collected samples, varies from 8.1 to 98.8 Bqm^{-3} with an average value 32.0 Bqm^{-1}. The radium concentration in collected samples varies from 26.1 to 323.0 $Bqkg^{-1}$ with an average value of 101.2 $Bqkg^{-1}$. The values obtained for the studied samples are within the internationally accepted recommended values. Finally, it can be concluded, from the obtained results that these samples from the Al-Qusair area may be used as safe sources in manufacturing the building materials [30].

1.10. Study Objectives

The main goals of this study are:

1. To measure the activity concentrations of ^{226}Ra in soil samples that will be collected from many sites in the northern part of the west bank (Tubas, Jenin, and Tulkarm Governorates).
2. To measure the radon concentration levels in these samples collected from the area under investigation.
3. To estimate the annual effective dose resulting from the exposure to these radionuclides.
4. Provide the database of radioactive elements in the area under investigation to arrive at an irradiation map for these elements and other radionuclides in Palestine.

It is hoped that this study might serve as the basis to draw a national map of radon concentration levels in Palestinian regions, to monitor and resolve any observed hazardous changes in the radon concentration levels from place to place and from season to season. Furthermore, it is also hoped that the study will pave the way for future there surveys to establish a Palestinian map of all types of radiation concentration on radon

CHAPTER TWO

SOME INFORMATION ABOUT OF RADON

Chapter 2- Some Information About Radon

2.1. Introduction of radon

In 1899, the radioactive gas formed by thorium was detected by Ernest Rutherford and Robert Owens. In the same year, a radioactive gas released by radium was detected. In 1900, in Halle, Germany, Friedrich Ernst observed a gas accumulation within radium ampoules and they watched radon. The radium was a more long-lived radon-222 isotope with a half-life of 3,82 days and the same isotope as found by the Curies. Rutherford's detection of radon-220 was 56 seconds long.

In 1900, Rutherford studied the new gas and demonstrated that it could condense to a liquid. William Ramsay and Robert Whytlaw-Gray collected ample radon in 1908 at University College, London, to define its characteristics, and reported the heaviest gas known [31].

2.2 Characteristics of Radon

2.2.1 What is Radon?

Radon, with the symbol "*Rn*", is a chemical element. It's a noble gas, radioactive, colorless, and odorless. In the ordinary radioactive degradation chain, thorium and uranium slowly disintegration into the lead, as well as other short-lived radioactive elements, occurs naturally at minute amounts. The immediate decay of radium is radon itself.

2.2.2 Physical and Chemical Properties of Radon

Radon is a gas without color, smells, and tasteless and cannot be detected only by humans. Radon is one of the densest gasses, at room temperature and the densest of the noble gases, at normal temperature and pressure. Radon formed a monatomic gas at a density of 9.73 kg/m^3 about eight times the density of the Earth's atmosphere, 1.217 kg/m^3. While colorless at standard temperature and pressure, if it is cooled below the freezing point of 202 K (-71 ° C; -96 ° F), radon emits radiological brilliance which transforms from yellow to orange roots when its temperature drops. It is slightly soluble

in water when condensation is obtained, but more soluble than lighter noble gasses. Radon, however, glows due to its high intensity of radiation. Inorganic liquids, radon is slightly more soluble than in water [32].

2.2.3 Radon isotopes and daughters

Thirty-nine isotopes with atomic masses ranging between 193 and 231 have been characterized. ^{222}Rn is the most stable isotope, the decay product being ^{226}Ra and the decreasing product ^{238}U. The (highly unstable) ^{218}Rn isotope also has a trace quantity of ^{222}Rn among the dugather [33].

Three other isotopes are greater than an hour's half-life: ^{211}Rn, ^{210}Rn, and ^{224}Rn. The ^{220}Rn isotope is a natural decay result of the most stable thorium isotope (^{232}Th) is a half – life 55,6 seconds long and has alpha radiation. Similarly, ^{219}Rn is based on the most stable actinium isotope (^{227}Ac) – called "actinium" – and is a half-life 3.96 seconds alpha emissary. The neptunium (^{237}Np) decay sequence does not contain any isotopes of radon, but traces of the (extremely unstable). But daughters ^{222}Rn, which has a half-time of 3,83 days and belongs in the radium and uranium-238 decay series. The first four items (except slight decline schemes) are very short-lived, which suggests that the decline represents the first distribution of radon [34].

When a closed volume is supplied with radon constantly, the concentration of short-lived isotopes increases until a balance has been achieved in which the decay rate of each decay is equal to that of the radon itself. The balance factor is 1 if the two events are the same, meaning that the products of decay have remained near enough to the parent of radon for several hours to do their balance [35].

Radon properties bind to surfaces or dust particles due to their electrostatic charge, where gaseous radon doesn't. The relation eliminates them from the air, which typically creates a balance factor less than 1 in the atmosphere. Often, air circulation or air filtration systems minimize the balance factor and increase airborne particulate matter, including cigarette smoke. In epidemiological trials, the equilibrium factor is 0.4 [36]. .

2.3 The Radon Sources in Environment

2.3.1 Sources of Radon in Soil

Radon atoms emanate from material by way of which an amount of material is released from the radon atoms. Radon release mechanisms from rock, soil, and other materials are not very well known and possibly not similar. Radon emanations were stated to be affected by the soil's condition and its porosity, humidity, temperature, and atmospheric pressures. The effect of the re-adsorption of the radon atom on the pores' surfaces decreases the radon release when the moisture content is very low.[37] On the other hand, the radon release rises to a certain humidity level if the moisture content increases much, above which the radon release decreases again due to the decrease of the diffusion in water-filled pores. The radon emanation from the soil was found to depend not only upon the concentration of ^{238}U and ^{226}Ra, but also on the composition, and permeability, of the rock and soil. The effect of coloration was found to decrease the radon emanation from the brick surfaces, which raises the amount of radon within the brick. The radon emanation from the unbundled region of the brick increases as the concentration of radon within the brick increases. The emanation of radon from gypsum and plaster-covered bricks has been found; hence the internal finish will increase the radon content inside the buildings [37].

Soil radon emission and exhalation rates vary from site to site as radium concentration variations and soil parameters such as the content of humidity, porosity, permeability, and grain size differ [37].

2.3.2 Sources of Radon in Air

The distribution of radon in the air is affected by the gradient of vertical temperature, the wind direction and intensity, and the air turbulence. Also, radiation and washing ratios affect the dispersion of radon-daughters. The amounts of radon progeny and wasting ratios are inversely associated with low levels of precipitation. It was found that there is a wide inverse association between the radon concentration and the wind speed. This connection has been clarified by the dispersion of radon in a greater volume because of the vertical mixture and Duran differences, under stable atmospheric conditions. The

effect of turbulence was also found to reduce the radon concentration with a mixing fan [37].

2.3.3 Sources of Radon in Water

Radon and radium in water are either subjected to water intake from the normal usage of the water or to the daily use of water inhalation. They are a danger to people's health. Radon solubility decreases with temperature due to cancellate behavior, but temperature dependence in the case of heavier gasses is much higher. Radon can be transported at a longer distance through groundwater [37].

2.4 Characteristics of Soil

2.4.1 Porosity of Soil

Soil porosity refers to soil pores. The flow of air and water is affected by porosity. There are many pores inside and between the aggregates in safe soils. Weak soils have few pores, cracks, or holes visible to them. The management of the soil will influence its porosity. See, for example, areas where students are walking around your school. When the grass is worn out and the soil exposed, it always looks different, since the structure and porosity have been compacted and modified. There are also areas where the water cannot drain from the puddles [38].

2.4.2 Grain-Size Distribution

The mechanical analysis calculates the size and percentage of the total dry weight of particles in soil that are present. The distribution of the soil in particles is normally done by two methods: (1) sieve analysis, with a diameter of more than 0.075 mm, and (2) hydrometer analysis, with smaller diameter particle dimensions than 0.075 mm [39].

Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings.

First, the soil gets oven-dry, and then, before passage through the sieves, all the lobsters are cut into tiny particles. In the seven shakers of the laboratory examination, Figure2 shows a collection of sieves. The mass of soil retained on each strain is determined after the completion of the shaking cycle. It may be hard to divide lumps into individual particles when cohesive soils are examined. In that case, it is possible to mix the soil with

water to create a slurry and then to wash the sieves. The portions kept on each sieve will be collected separately and oven-dried before the calculation of the mass kept on each sieve.

The study of the hydrometer is based on the sedimentation theory of soil grains in water. If a soil sample is dispersed into water, the particles settle down at various speeds, depending on their shape, scale, weight, and water viscosity. To be simple, all the solar particles are presumed to be spheres [39].

Figure 2.1 Set of sieves in a sieve shaker

2.4.3 Moisture Content in Soil

Soil moisture is the water that is contained in the soil and is influenced by precipitation, soil temperatures, etc. The same factors help to assess the type of biome and the suitability of the soil for cultivation. The health of our plants is dependent, among other things, on adequate moisture and soil nutrients. Due to the decrease in moisture supply, normal plant function and growth are disrupted and crop production is reduced. And the supply of moisture is increasingly unpredictable as our environment shifts. The amount of water stored in the soil is not constant with time but may vary [39].

2.5 The Production of Radon in soil

2.5.1 Radium in Soil

Radium is a toxic metal naturally occurring it's one of the isotopes that exist. He's here developed during a decay in uranium and thorium. The surroundings. In the natural world, Low levels of radium in soil and water are found in meat, coal, and plants.[40]

Radium is not a stable element. Like radium decays, radiation release, and decay products. Some of these decay like radium Products also emit radiation and other types of Elements. The process of decay proceeds to The substance is composed of a stable, non-radioactive decay.[40]

Radiation during the decay process is release gamma, beta, and an alpha particle. Alpha particles can only travel short distances and not human penetration skin. Beta particles are normally absorbed don't cross the body, skin. However, gamma radiation can penetrate the Body. Isotopes of radium decay to form a radioactive radon gas isotope. The time it takes for a 50% loss of radioactive material radioactivity is called half-life by a decrease. The half-life for radium-224, radium-226, and radium 228 is 3.63 days, 1600 years, and 5.75 years, respectively. [40] The most common radium isotopes after Each of which forms a radon isotope. Radium exposure can lead to several different harmful effects over a long time. When inhaled as dust or ingested as a contaminant, the risk of many conditions such as lymphoma, bone cancer, and hematopoietic diseases is increased in diseases such as leukemia and plastic anemia (blood formation). It takes years to produce these results. If the risk of cancer is increased in almost every tissue and organ, though in various degrees when exposed externally to radium gamma radiation [40].

2.5.2 Radon diffusion in Soil

The degree of water saturation of the soil pores has a strong effect on radon diffusion through the soil. Methods for calculating the coefficient of radon diffusion were developed by several researchers. [41]To estimate the radon diffusion coefficients for typical types of soil in Japan, we built a new experimental method and applied it to typical water loam at different levels of saturation (0-0.82). The device consists of a sparkling cell, a solar column, an accumulator tank, and a source of radon. The radon concentrations in the accumulation tank are stable and are continuously monitored by the

passive scintillation cell, which is diffused through the soil column. The coefficients of radon diffusion for the loam samples ranged between $9.60\times10^{-6}m^2\,s^{-1}$and $1.27\times10^{-7}m^2s^{-1}$. In general, for the water saturation range of 0-0.4, diffusion coefficients are approximately constant, and the water saturation decreases from 0.4 to 0.82 [41].

2.6 The Concentrations Guidelines of Radon in Soil

At long-term average radon concentrations, the risk of lung cancer increases by 16% per 100 Bq/m^3 increase[42]. The dose-response relationship is linear; such as, with increasing radon exposure, the risk of lung cancer increases proportionally establishing a national annual average concentration reference level of 100 Bq/m^3, but if this level cannot be reached under the prevailing country-specific conditions, the reference level should not exceed 300 Bq/m^3 [42].

2.7 Health Effects of Radon

Radon is quickly scattered through the air as it reaches the house. The process of radioactive decay leading to the development of radon is not prevented. This results in the decay of radon into other radioactive elements known as radon decay. These decays consist of polonium, plum, and bismuth of various types. In comparison to the gas radon, solid particles are the radon degradation products made from the radon. As the decaying radon gas shapes, these particles are suspended in the air. These particles are very small and are not visible. As radon degradation products are extremely small particles, they can quickly inhale and bind to the lung tissue. They have very short half-lives which means that after they are created, they will decay relatively fast. Indeed, once inhaled, it will rot in the lungs until the lungs can be cleaned up[43].

When radon degradation is inhaled, the susceptible lung tissues adhere to them. When they are short-lived, they die while in the lungs and expose the lung tissue to radiation. As radon decays, alpha, beta, and gamma radiation are released. The two radon decay products - polonium 218 and polonium 214 - are potentially most harmful by alpha radioactive radiation in the form of particles[43].

The decay of radon decreasing products allows alpha particles to damage sensations in lung tissue. In most cases, the lung tissue cell is destroyed so the body can repair it. The alpha particles can therefore influence the DNA or cause a chemical reaction affecting the

DNA. The cell will mutate when this happens. This is the mechanism used to enhance the potential of lung cancer by repeated exposure to radon and radon decay materials. Radon decay products bind to delicate lung tissue when inhaled. [43]They can collapse as long as they're in the lungs, becoming short-lived. The lung tissue is exposed to radiation. When the released alpha particle hits a living cell and enters the nucleus inside the cell, it affects the DNA inside the nucleus and the cancer suppressive gene is disrupted inside the DNA and an increased risk for lung cancer may occur. Alpha particles can also induce ionization of the material around the DNA, as well as the alpha particle that induces it .His process is used to raise the risk of lung cancer in radon (and in particular, radon decay products) [43].

2.8 Methods to Reduce Radon Concentration in Soil

The gas diffuses in construction materials from soil to buildings by pores. Radon also emanates from building materials and gets into water migration indoors. The radon levels can be decreased using polymer compositions that fill pores into building materials and reduce radon and water molecules' permeation coefficient in building materials (concrete, gypsum, etc this decreases radon levels. The paper explores and chooses polymer silico-organic compounds as the chemicals to keep radon from springing indoors [44].

Radon levels can be lowered in existing homes by Increased ventilation under the floor; Installation in the basement or under a solid floor of a radon sump system; avoiding the transition of radon to living rooms from the basement; Floors and walls sealing, and Improve the house's ventilation [44].

CHAPTER THREE

EXPERIMENTAL TECHNIQUE

Chapter 3- Experimental Technique

3.1. Study Area

Six of the eleven districts of Northern West Bank representing the West Bank are based on the administrative division of the Palestinian Authority. These areas are as follows:

1. District of Nablus

2. District of Jenin

3. District of Tulkarm

4. District Qalqilia

5. District of Tubas

6. District Salfit

But the study area is Tubas, Jenin, and Tulkarm Governorates, respectively.

3.1.1. Geography

The northern part of the West Bank is strategically placed since it is located in the center of four regions and connects them. Geographically, the West Bank is mostly composed of north–south–oriented mountains, having an average height of 400 to 1020 meters. The hills descend eastward to the low-lying rift valley of the Jordan River and the Dead Sea. The west bank does not lie entirely within the drainage system of the Jordan River, as higher areas in the west give rise to the headwaters of streams flowing westward to the Mediterranean Sea [45].

It has a territory of 5655 km^2, with 2921,170 people at the end of the nation 2018 year. Area of analysis indicates the north of the West Bank districts including Nablus 388 321 individuals, Qalqilya 112,400 individuals, Jenin 314,866 individuals, Tulkarm 186,760 individuals, and Salfit with 60,927 individuals [45,46].

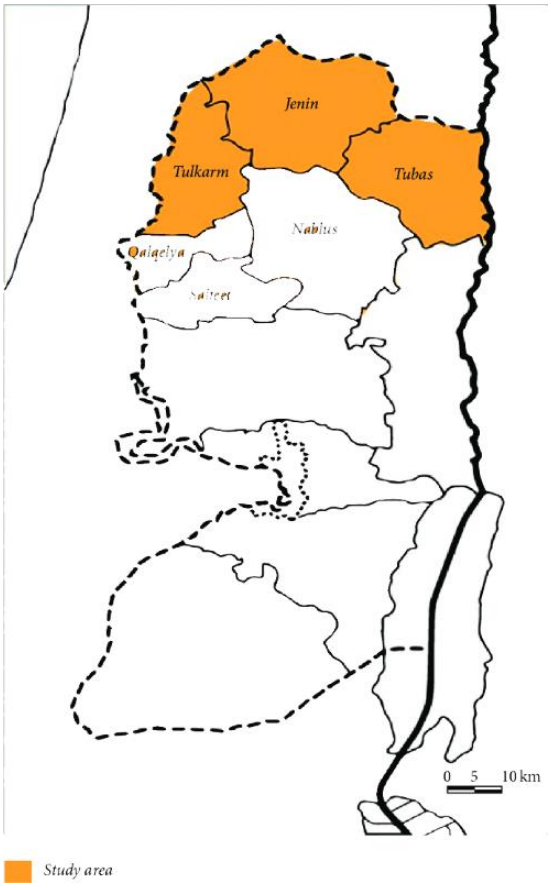


Figure 3.1: West Bank map including the north districts [46].

3.1.2 Climate

The Mediterranean climate characterizes the climate of the West bank. The Mediterranean climate, marked by mild temperatures and a lot of rainfall, covers most of the north of the West Bank. Only Tubas is found on the eastern slopes away from the marine effects within the semi-arid climate. The yearly average temperature varies from 17°C to 23°C [47].

3.2 Methodology

3.2.1 Samples locations

Forty surface dry soil samples have been collected from various places in the regions of Jenin, Tulkarm, and Tubas. The zones are Jenin north of the city Ya'bad, Qabatiya, Zababida, Meithalun, Hadad, Salem in Jenin governorate; Qaffin, Baqa asharqiya,

An Nazla al-Gharbiya, Zeita, Attil, Deir al-Ghusun, Jarushiya, Irtah, Anabta, Kafr al-Labad) , Shwaika, Iktaba in Tulkarm governorate and Tubas- Al'Aqaba Tubas- Gore Zone in Tubas governorate.

3.2.2 Samples collection

Each sample was collected using a template 30 cm by 30 cm and 5 cm depth in an area of the surface layer. The outer layer of the soil has been removed because it has various wastes and impurities. About 1 kg of each sample was collected in a plastic bag at the sampling points.

3.2.3 Samples preparation

Soil samples were well mixed after exotic materials such as pieces of stones gravel were removed. First, all samples are sieved in 1 mm a mesh sieve and dry up then at 110 °C for 12 h to a hot air oven to ensure material homogeneity and to expel all moisture contents in samples. Samples were weighed and stored for measurements [48, 49].

3.3 Measurement Techniques

The equipment for radon monitoring is classified into two parts: passive and active devices.

3.3.1 Passive Techniques

There is no power needed for passive radon testing devices to operate. Radon detectors, such as charcoal canisters, alpha-track detectors, liquid scintillation instruments for charcoal, and electric ion chamber detectors, are included. For a specified time, these devices are exposed to the air in the home and then sent for examination to a laboratory [50].

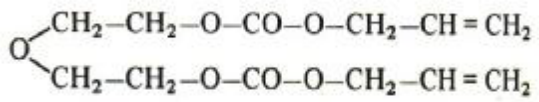
3.3.1.1 Solid state nuclear track detectors SSNTDs (CR 39 detectors)

Solid-state detectors are used for precise radiation measurements. While solid-state detectors are based on ionization, they are very highly efficient. Different from chambers of ionization, proportional counters, and Geiger Meters Counters. Solid-state detectors (SSNTD) have been used for Radon measurements, a long period. SSNTD is alpha-sensitive to Particles that are in the energy spectrum of radon-emitted particles. Additionally, Beta and gamma rays are largely insensitive to SSNTDs. On the other side, Words, beta and gamma rays do not generate single tracks. SSNTDs also benefit most

from the lack of moisture, low moisture. Moderate heat and light temperatures. Naturally, they don't need the source of energy to be run because its property is an intrinsic material quality made from them[51].

Three forms of SSNTDs available commercially are:

1- $C_{12}H_{18}O_7$, classified as CR-39, polyallyl diglycol, with CR-39 Clear, colorless, rigid plastic, 1.30 gcm^{-3} density, and Structure of the chemical:



2- Cellulose nitrate ($C_6H_8O_8N_2$) is known as CR-85.

3- Plastic track detector is known as CR-115

CR-39 is a better detector than other radon detectors used to measurement concentrations. This is because of the benefits of CR-39 detector measurement of the cheap and easily available. This type of detector has been used all over our work to produce a reasonable result. CR-39 is a transparent plastic that is stable and sensitive to energetic protons, alpha particles, and heavier nuclei. After exposure, the tracks are revealed in solutions such as caustic alkalis by etching the material [51].

3.3.1.2 Preparation of dosimeters

The scanning technique was used to measure radon concentration in soil samples collected from the area under investigation. Radon and his daughters are reaching out a concentration of equilibrium after a 1 week or more and thus a concentration of equilibrium .

Equilibrium of the emerging radon activity could be obtained from the time of exposure and container geometry. This one ,a step was essential to ensure that the radon gas and its daughters were concentrated in the sample. The samples were carefully sealed for 75 days in cylindrical containers of a good type of plastic 6.5 cm in diameter and 12 cm in depth. One CR-39 detector was fixing below the cork head at a certain distance (about 1.5 cm) from the surface of the soil sample. The sensitive part of the detector was confronted with the emanation of radon from the soil sample so that the alpha could be recorded particles resulting from the decay of radon in the entire volume of the can. Each sample container

has been tightly capped to a cylindrical plastic inverted cover as shown in (Fig 3.2). [52,53]

During the exposure time of alpha-particles from decay, radon and their daughters are shelling the CR-39 detector in the volume of air in cylindrical containers. After a fixed time, the Detectors were collected and etched in the solution (6.25 M NaOH at 70 °C for 4 h) and the detector was washed in distilled water and allowed to air dry. Manually, the tracks were counted by randomly selected 10 fields of views by using an optical microscope with a magnification of 160x , to get an average value of track density for each detector. The area of the field of view was calculated and found to be equal to about (0.0133 cm^2); the average number of tracks per field of view was used to count the track density per m^2 [54,55].

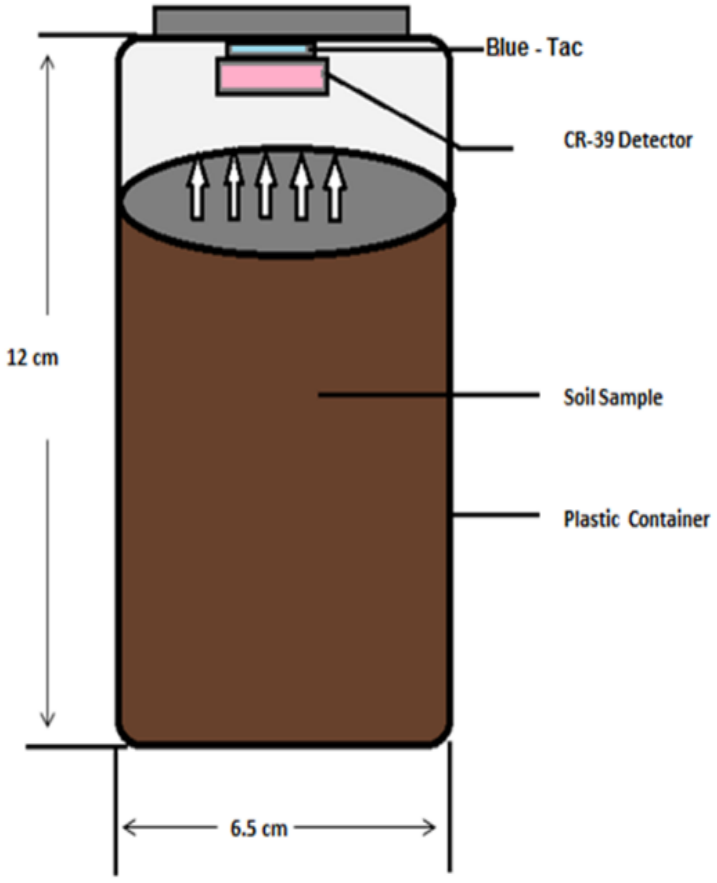


Figure 3.2: Experimental setup for the measurement of radon concentration.

3.3.1.3 Detectors scanning counting tracks

Generally, the primary requirement is simply to count etched tracks on a detector. The sizes and shapes of the etch pit "track" will vary: vertically circular etch pits will form incident alpha particles. While the majority of the etch pits would be elliptical as a result of an incident of alpha particles on the surface detector for shallower dip angles. Then repeatedly ignore some easily discounted are smaller to etch pits and any scratches [56]. The authentic track of the to etch pit can be detected by slowly shifting the microscope's fine focus up and down and looking for a bright point at which light is internally reflected in the bottom tip of the etch-pit cone shows that figure 3. 3.

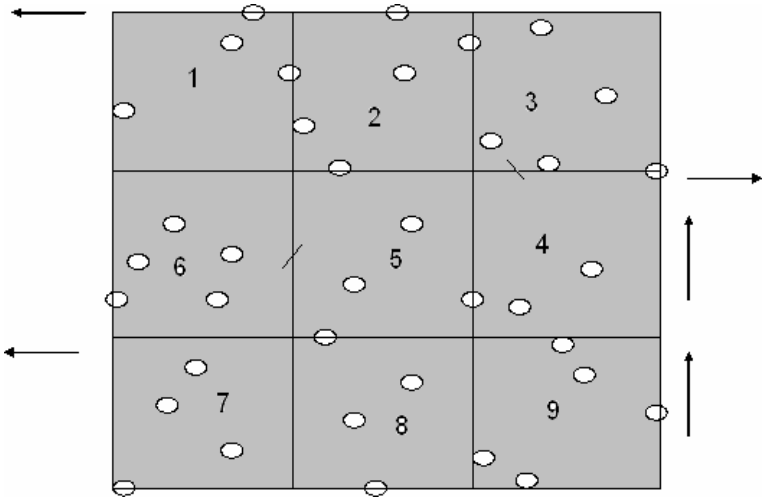


Figure 3.3: The shape of a pit in a detector.[56]

3.3.2 Active Techniques

Active devices for radon testing or measuring need the power to operate. Educated, state-certified testers require the operation of active radon detectors such as continuous radon monitors and continuous working-level monitors. They function by constantly measuring and recording the amount of radon in the home's air, soil, and water or its decay items. Many of these instruments include a summary of this data which during the test period will show any unusual or irregular swings in the radon level. This process can be explained by a competent, state-certified tester example it is Durridge RAD7 Soil continuous radon monitor [57]. The RAD7 detector converts alpha radiation directly to an electrical signal and can determine the energy of each particle by electronic means, allowing the identification of an electrical signal. Radiation produced isotopes (^{218}Po,

^{214}Po) so that it is possible to distinguish instantly between old and new radon, radon from Thoron, and the noise from signal [58].

3.4 Theoretical calculations

3.4.1 Calculations of radon concentrations

The concentration of radon in secular equilibrium (C_{Rn}) can be estimated by the equation:

$$C_{Rn}(Bqm^{-3}) = \frac{c_0 t_0}{\rho_0}\left(\frac{\rho}{t}\right) = k\left(\frac{\rho}{t}\right) \qquad (3.1)$$

Where C_0 is the activity concentration of ^{226}Ra (solid radon source) equal 800 Bqm^{-3}; ρ_0 is the track density (number of tracks cm^{-2}) in detectors exposed to ^{226}Ra; t_0 is the exposure time (in days) of detectors are exposed to ^{226}Ra, equal 70 days; k is the calibration factor, equal 24.2 Bq/m^3 day/tracks/cm^2; ρ is track density (number of tracks/cm^2) in detectors exposed to soil samples and t is the exposure time (in days) of detectors exposed to soil samples, equal 75 day[59].

3.4.2 Annual Effective Dose

To obtain the annual effective dose due to the radon concentrations received by the individuals, one has to take into account the conversion coefficient from the absorbed dose and the indoor occupancy factor. By using the UNSCEAR recommendation, the annual effective dose for one-year radon exposure can be estimated by using the relation [60, 61]:

$$AED(mSvy^{-1}) = C_{Rn} * F * T * Q \qquad (3.2)$$

Where, F (is the conversion factor) = 9 nSv (Bq·hm^{-3}) $^{-1}$; T is 8760 hours of a year (Assuming an indoor occupancy factor is about 80% of 8760 hours, which equals 7008 hours and 20% for outdoors, which equals1752 hours); and Q is the equilibrium fraction (0.6) for outdoors and (0.4) for indoors [61].

From equation (3.2), we can calculate the annual effective dose for indoors and outdoors according to the following relations [62]:

$$AEDin(mSvy^{-1}) = 0.02523\ C_{Rn} \qquad (3.3)$$

$$AEDout(mSvy^{-1}) = 0.00946\ C_{Rn} \qquad (3.4)$$

3.4.3 Determination of Radium Contents in Soil

The radium concentration (C_{Ra}) in soil samples was calculated by using the following relation [63, 64]:

$$C_{Ra} = \frac{\rho h A}{k T_e M} \qquad (3.5)$$

Where ρ is the track density (tracks per cm^2); h is the distance between the detector and the top of the sample; A is the surface area from which radon is exhaled (m^2); M is the mass of the sample (kg); and T_{eff} is the effective exposure time in (hr), which is related to the actual exposure time t, by the relation:

$$T_e = t - \frac{1}{\lambda(1 - e^{-\lambda t})} \qquad (3.6)$$

Where λ is the decay constant of radon ($\lambda = 7.56\times10^{-3}\ h^{-1}$).

3.4.4 The radon exhalation rate

The radon exhalation study is important for understanding the relative contribution of the material to the total radon concentration found in the dwellings. The equation used for surface exhalation rate is written as [22] :

$$E_A = \frac{Cv\lambda}{AT_{eff}} \qquad (3.7)$$

And for mass exhalation rate is written as

$$E_M = \frac{cv\lambda}{MT_{e_{ff}}} \qquad (3.8)$$

Where; E_A ($Bqm^{-2}h^{-1}$): is the surface radon exhalation rate, E_M ($BqKg^{-1}h^{-1}$): is the mass radon exhalation rate, C: is the integrated radon exposure in (Bqm^{-3} h), V: is the void volume of the container (m^3), A: is the area of the sample (m^2), M: is the mass of the sample (kg).

3.4.5 The Dissolved Radon Concentration

The dissolved radon concentration (C_S) in soil samples is calculated using the following equation [60, 62] :

$$C_S(Bqm^{-3}) = \frac{h\ t\ \lambda\ C_{Rn}}{L} \qquad (3.9)$$

Where L is the depth of the sample in (m), λ is the decay constant of radon ($\lambda = 7.56\times10^{-3}$ h^{-1}), h is the distance between the detector and the top of the sample , t is the exposure time (in days) of detectors exposed to soil samples, equal 75 day, C_{Rn} Concentration of Radon.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Chapter 4- Results and Discussions

4.1 Introduction

In the present work, it was done a total of forty measurements of radon concentration in the region of North West Bank (Tubas, Tulkarm, Jenin) Governorates.

In this chapter, the results and discussion for radon concentration, radon exhalation rate, radium concentration, and the annual effective dose for collecting soil samples have been documented.

Equations 3.1 through 3.9, respectively, were used for calculating radon concentration, the annual effective dose, the radium concentration, the radon exhalation rate, and dissolved radon concentration in a soil sample and the results are summarized in tables 4.1 to 4.9. Table 4.10 represented a comparison of radon concentration levels in soil samples at the present work with those in Palestine. The correlation between radon concentration with the site is represented in figures 4.1, 4.3, and 4.5 for (Tulkarm, Jenin, Tubas), respectively. The correlation between radium concentration with radon concentration is represented in Figures 4.2, 4.4, and 4.6 for (Tulkarm, Jenin, Tubas), respectively.

4.2 Results of Measurements

4.2.1 Results of Measurements in Tulkarm Governorate

Table 4.1, shows the values of radon concentrations, radium concentrations, and dissolved radon concentrations in soil samples collected from different sites in the Tulkarm Governorate -Palestine. It is seen that the values of radon concentration in the collected samples vary from 281.0 Bqm^{-3} to 826 Bqm^{-3} with an average value of 505.2 Bqm^{-3}. It is noteworthy from Table 4.1, that the radon concentration of soil samples is the highest in the Illar site (826 Bqm^{-3}) but the least in the Shwika site (281Bqm^{-3}). The values of radium concentration are the highest in Illar (36.0 Bq/Kg) but the least in the Shwika site (12.0 Bq/Kg). The dissolved radon concentration of the soil sample is the highest in the Illar site (977.8 Bq/m^3) but the least in the Shwika site (332.0 Bq/m^3).

Table 4.1: Radon concentration (C_{Rn}), Radium concentration (C_{Ra}), and dissolved radon concentration (C_S) in Tulkarm Governorate.

Site	Sample Code	C_{Rn} (Bq/m^3)	C_{Ra} (Bq/Kg)	C_s (Bq/m^3)
Qaffin	Tuss 1	465.6	20.0	551.0
Baqa asharqiya	Tuss 2	476.6	20.8	564.0
An Nazla al-Gharbiya	Tuss 3	498.4	21.7	589.8
Zeita	Tuss 4	701.7	30.6	830.0
Illar	Tuss 5	826.0	36.0	977.8
Attil	Tuss 6	681.0	29.7	805.8
Deir al-Ghusun(1)	Tuss 7	542.0	23.6	641.5
Deir al-Ghusun(2)	Tuss 8	453.6	19.8	536.7
Jarushiya	Tuss 9	362.9	15.8	429.0
Shwaika	Tuss 10	281.0	12.0	332.0
Bal"a	Tuss 11	377.0	16.0	446.0
Iktaba	Tuss 12	365.0	16.0	432.0
Tulkarm western region	Tuss 13	524.6	22.9	620.8
Anabta	Tuss 14	618.7	27.0	732.0
Kafr al-Labad	Tuss 15	436.1	19.0	516.0
Irtah (1)	Tuss 16	474.0	20.7	561.0
Irtah(2)	Tuss 17	503.9	22.0	596.0
Min		**281**	**12**	**332**
Max		**826**	**36**	**978**
Average		**505.2**	**22**	**598**

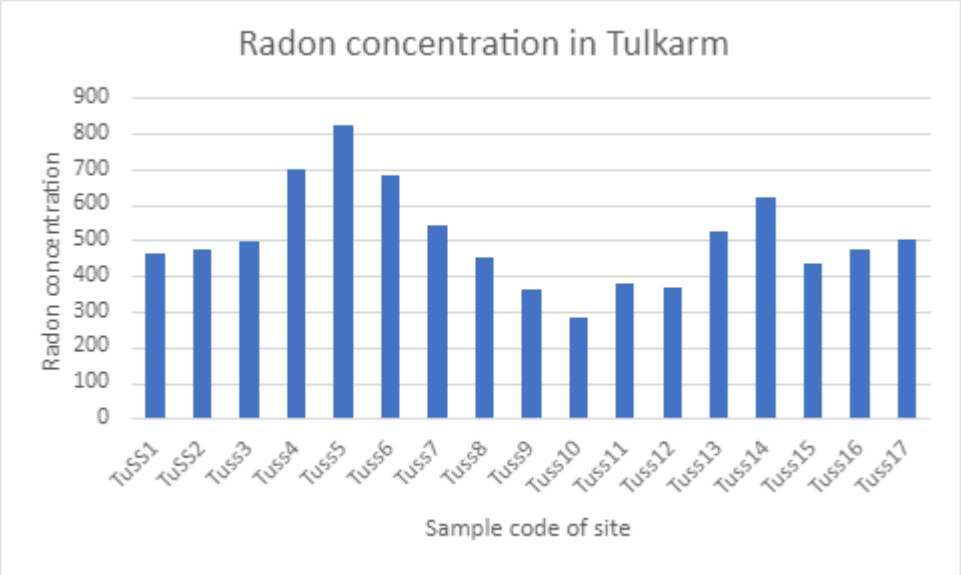


Fig 4.1: The Radon concentration in Tulkarm Governorate

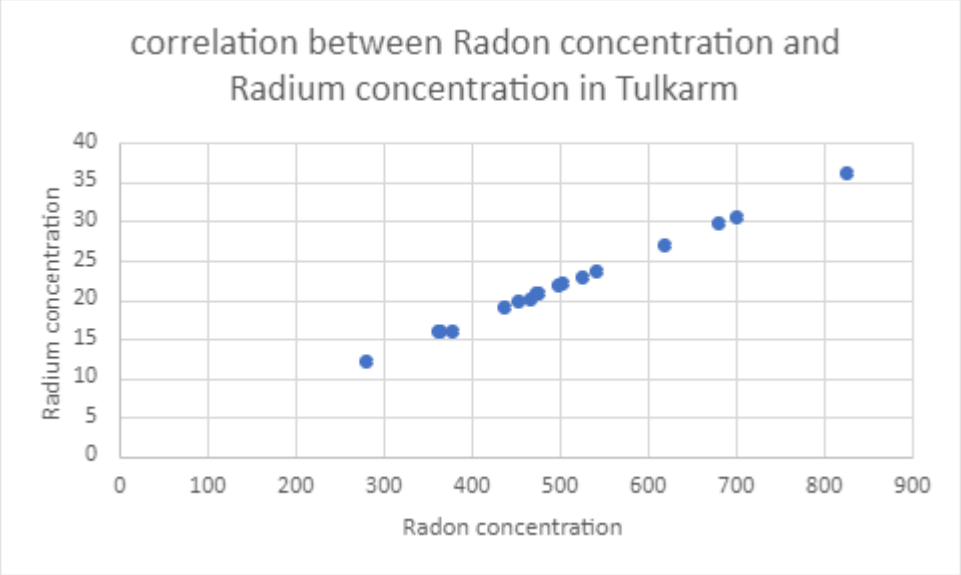


Fig 4.2: The correlation between radium concentrations (C_{Ra}) with radon concentration (C_{Rn}) in Tulkarm Governorate

Table 4.2, shows the values of the surface and mass exhalation rates of radon for soil samples collected from different sites in the Tulkarm Governorate. The surface exhalation rate in these collected samples varies from 263.7 $mBqm^{-2}$ h^{-1} (Shwaika) to 775.6 $mBqm^{-2}$ h^{-1} (Illar site) with a total average value of 474.17 $mBqm^{-2}$ h^{-1}. The mass

exhalation rate has been found to vary from 6.0 mBqkg^{-1} h^{-1} to 18 mBqkg^{-1} h^{-1} with an average value of 11.1 mBqkg^{-1} h^{-1}.

Table (4.2): The surface Exhalation Rate (E_A) and the Mass Exhalation Rate (E_M) in Tulkarm Governorate.

Site	Sample Code	E_A (mBqm^{-2}h^{-1})	E_M (mBqKg^{-1}h^{-1})
Qaffin	Tss 1	437.0	10.0
Baqa asharqiya	Tss 2	447.0	10.6
An Nazla al-Gharbiya	Tss 3	467.8	11.0
Zeita	Tss 4	658.7	15.6
Illar	Tss 5	775.6	18.0
Attil	Tss 6	639.0	15.0
Deir al-Ghusun(1)	Tss 7	508.9	12.0
Deir al-Ghusun(2)	Tss 8	425.8	10.0
Jarushiya	Tss 9	340.6	8.0
Shwaika	Tss 10	263.7	6.0
Bal"a	Tss 11	354.0	8.0
Iktaba	Tss 12	342.7	8.0
Tulkarm western region	Tss 13	492.5	11.7
Anabta	Tss 14	580.7	13.7
Kafr al-Labad	Tss 15	409.0	9.7
Irtah (1)	Tss 16	445.0	10.5
Irtah(2)	Tss 17	473.0	11.0
Min		**263.7**	**6.0**
Max		**775.6**	**18.0**
Avarege		**474**	**11**

Table 4.3, shows the values of the annual effective dose, AED_{in}, AED_{out}, and AED_{tot} in Tulkarm Governorate. The total annual effective dose, AED_{tot} in these soil samples varies

from 9.7 (in Shwaika site) to 28.6 $mSvy^{-1}$ (in Illar site) with an average value of 17.5 $mSvy^{-1}$.

Table 4.3: The annual effective dose for indoors (AED_{in}) and outdoors (AED_{out}) and the total annual effective dose (AED_{tot}) in Tulkarm Governorate.

Site	Sample code	AED_{in} ($mSvy^{-1}$)	AED_{out} ($mSvy^{-1}$)	AED_{tot} ($mSvy^{-1}$)
Qaffin	Tss1	11.7	4.4	16.1
Baqa asharqiya	Tss2	12.0	4.5	16.5
An Nazla al-Gharbiya	Tss3	12.6	4.7	17.3
Zeita	Tss4	17.7	6.6	24.3
Illar	Tss5	20.8	7.8	28.6
Attil	Tss6	17.2	6.4	23.6
Deir al-Ghusun(1)	Tss7	13.7	5.1	18.7
Deir al-Ghusun(2)	Tss8	11.4	4.3	15.7
Jarushiya	Tss9	9.2	3.4	12.6
Shwaika	Tss10	7.0	2.7	9.7
Bal"a	Tss11	9.5	3.6	13.1
Iktaba	Tss12	9.2	3.5	12.7
Tulkarm western region	Tss13	13.2	5	18.2
Anabta	Tss14	15.6	5.8	21.4
Kafr al-Labad	Tss15	11	4.1	15.1
Irtah (1)	Tss16	12	4.5	16.5
Irtah(2)	Tss17	12.7	4.8	17.5
Min		**7.0**	**2.7**	**9.7**
Max		**20.8**	**7.8**	**28.6**
Average		**12**	**4**	**17**

4.2.2 Results of Measurements in Jenin Governorate

Table 4.4, shows the values of radon concentrations, radium concentrations, and dissolved radon concentrations in soil samples collected from different sites in the Jenin Governorate -Palestine. It is seen that the values of radon concentration in the collected samples vary from 116.0 Bqm^{-3} to 746.0 Bqm^{-3} with an average value of 528 Bqm^{-3}. It is noteworthy from Table 4.4 that the radon concentration of soil samples is the highest in Salem village site -middle 2 (746 Bqm^{-3}) but the least in the Jenin city roundabout site (116 Bqm^{-3}). The values of radium concentration are highest in Salem village site-middle2 (32.5Bq/Kg) but the least in the Jenin city roundabout site(5.1Bq/Kg). The values of dissolved radon concentration are highest in Salem village site- middle2 (882.0Bq/m^3) but the least in the Jenin city roundabout site(137.0Bq/m^3).

Table 4.4: Radon concentration (C_{Rn}), Radium concentration (C_{Ra}), and dissolved radon concentration (C_S) in Jenin Governorate

Site	Sample Code	C_{Rn} (Bq/m^3)	C_{Ra} (Bq/Kg)	C_s (Bq/m^3)
Jenin north of the city	Jss1	442.7	19.3	523.8
Jenin city roundabout	Jss2	116.0	5.1	137.0
Salem -Entrance village	Jss3	565.0	24.6	668.7
Salem -middle village 1	Jss4	678.0	29.6	803.2
Salem -middle village 2	Jss5	746.0	32.5	882.0
Entrance Ya'bad	Jss6	439.4	19.2	520.0
Ya'bad-Middle of village	Jss7	571.7	24.9	676.5
Ya'bad- south of the village	Jss8	416.4	18.2	492.8
Qabatiya_north	Jss9	593.5	25.9	702.0
Qabatiya_middle of village	Jss10	547.6	24.0	648.0
Zababida-Arab American University	Jss11	280.9	12.3	332.4
Zababida-Arab as suweitat 1	Jss12	489.7	21.4	579.4
Zababida-Arab as Suweitat 2	Jss13	472.2	20.6	558.7
Entrance Meithalun	Jss14	509.4	22.2	602.7
Meithalun_North1	Jss15	475.5	20.7	562.6
Meithalun_North2	Jss16	625.0	27.3	739.8
Meithalun_middle of village	Jss17	722.5	31.5	855.0
Jenin Hadad 1	Jss18	638.3	27.8	755.0
Jenin Hadad 2	Jss19	710.5	31.5	840.7
Min		**116**	**5**	**137**
Max		**746**	**33**	**882**
Average		**528.0**	**23**	**625**

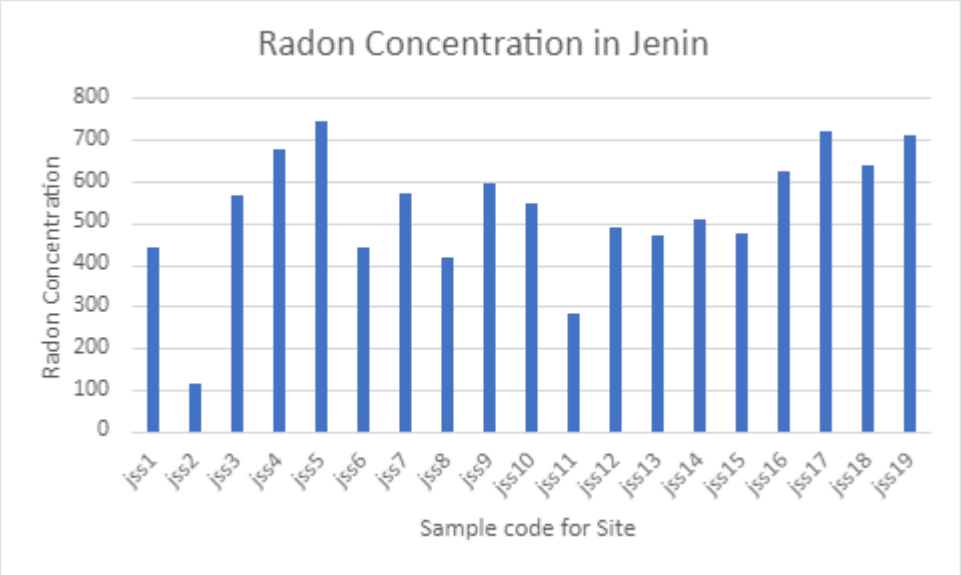


Fig. 4.3 The correlation between radon concentrations with the site for Jenin governorate.

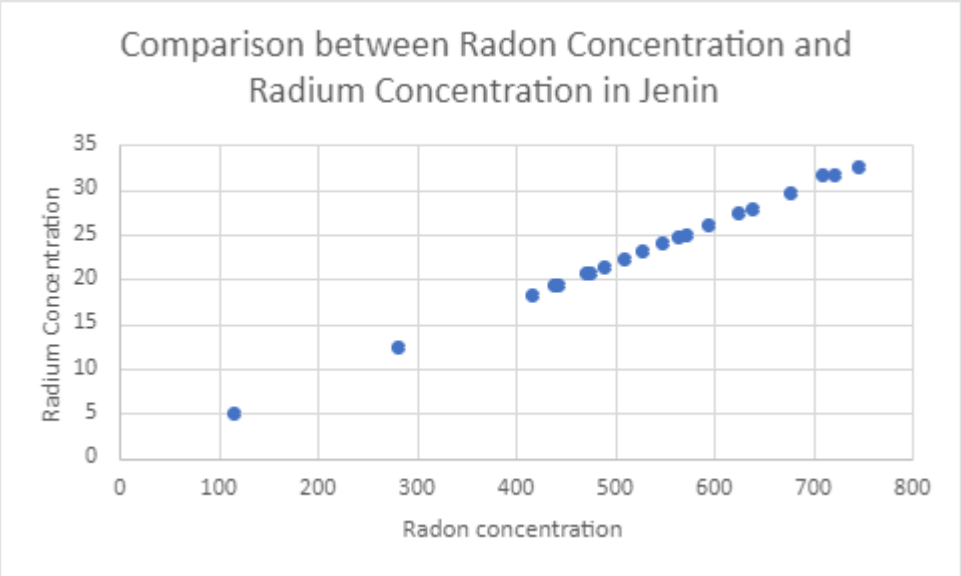


Fig. 4.4 The correlation between radium concentrations (C_{Ra}) with radon concentration (C_{Rn}) in Jenin governorate.

Table 4.5, shows the values of the surface and mass exhalation rates of radon for soil samples collected from different sites in the Jenin region. The surface exhalation rate in these collected samples varies from 108.8 $mBqm^{-2}\ h^{-1}$ (Jenin city roundabout) to 699.7 $mBqm^{-2}\ h^{-1}$ (Salem -middle site 2 site) with a total average value of 495.9 $mBqm^{-1}\ h^{-1}$. The mass exhalation rate has been found to vary from 2.6 $mBqkg^{-2}\ h^{-1}$ to 16.5 $mBqkg^{-1}\ h^{-1}$ with an average value of 11.73 $mBqkg^{-1}\ h^{-1}$.

Table(4.5): The surface Exhalation Rate (E_A) and the Mass Exhalation Rate (E_M) in Jenin Governorate.

Site	Sample code	E_A ($mBqkg^{-2}\ h^{-1}$)	E_M ($mBqkg^{-1}\ h^{-1}$)
Jenin north of city	jss1	415.5	9.8
jenin city round about	jss2	108.8	2.6
Salem -Entrance city	jss3	530.4	12.5
Salem -middle city 1	jss4	637	15
Salem -middle city 2	jss5	699.7	16.5
Entrance Ya'bad	jss6	412.5	9.7
Ya'bad-Middle of city	jss7	536.6	12.7
ya'bad- south of city	jss8	391	9.3
Qabatiya_north	jss9	557	13.2
Qabatiya_middle of city	jss10	514	12.2
Zababida-Arab American University	jss11	263.68	6.2
Zababida-Arab as suweitat 1	jss12	459.6	10.9
Zababida-Arab as suweitat 2	jss13	443	10.5
Entrance Meithalun	jss14	478	11.3
Meithalun_North1	jss15	446	10.6
Meithalun_North2	jss16	586.9	13.9
Meithalun_middle of city	jss16	678.2	16.1
Jenin Hadad 1	jss17	599	14.2
Jenin Hadad 2	jss18	667	15.8
Min		108.8	2.6
Max		699.7	16.5
Average		496	11

Table 4.6, shows the values of the annual effective dose, AED_{in}, AED_{out}, and AED_{tot} in Jenin Governorate. The total annual effective dose, AED_{tot} in these soil samples varies from 4.1 (in Jenin city roundabout site) to 25.8 $mSvy^{-1}$ (in Salem-middle site 2) with an average value of 18.3 $mSvy^{-1}$.

Table (4.6): The annual effective dose for indoors (AED_{in}) and outdoors (AED_{out}) and the total annual effective dose (AED_{tot}) in Jenin Governorate.

Site	Sample code	AED_{in} ($mSvy^{-1}$)	AED_{out} ($mSvy^{-1}$)	AED_{tot} ($mSvy^{-1}$)
Jenin north of city	Jss 1	11.2	4.2	15.4
Jenin city round about	Jss 2	3.0	1.1	4.1
Salem -Entrance village	Jss 3	14.3	5.3	19.6
Salem -middle village 1	Jss 4	17.1	6.4	23.5
Salem -middle village 2	Jss 5	18.8	7.0	25.8
Entrance Ya'bad	Jss 6	11.1	4.2	15.3
Ya'bad-Middle of village	Jss 7	14.4	5.4	19.8
Ya'bad- south of village	Jss 8	10.5	4.0	14.5
Qabatiya_north	Jss 9	15.0	5.6	20.6
Qabatiya_middle of village	Jss 10	13.8	5.18	19.0
Zababida-Arab American University	Jss 11	7.1	2.65	9.75
Zababida-Arab as suweitat 1	Jss 12	12.4	4.6	17.0
Zababida-Arab as Suweitat 2	Jss 13	11.9	4.5	16.4
Entrance Meithalun	Jss 14	12.9	4.8	17.7
Meithalun_North1	Jss 15	12.0	4.5	16.5
Meithalun_North2	Jss 16	15.8	5.9	21.7
Meithalun_middle of village	Jss 17	18.2	6.8	25
Jenin Hadad 1	Jss 18	16.1	6.0	22.1
Jenin Hadad 2	Jss 19	18.0	6.7	24.7
Min		**3.0**	**1.1**	**4.1**
Max		**18.8**	**7.0**	**25.8**
Average		**13**	**5.0**	**18**

4.2.3 Results of Measurements in Tubas Governorate

Table 4.7, shows the values of radon concentrations, radium concentrations, and dissolved radon concentrations in soil samples collected from different sites in the Tubas Governorate -Palestine. It is seen that the values of radon concentration in the collected samples vary from 346.5 Bqm^{-3} to 650.4 Bqm^{-3} with an average of 515.3 Bqm^{-3}. It is noteworthy from Table 4.7 that the radon concentration of soil samples is the highest in the Tubas- Gore Zone 1 site (650.4 Bqm^{-3}), but the least in Tubas- Al'Aqaba 1 site (346.5Bqm^{-3}). The values of radium concentration are the highest in Tubas- Gore Zone 1 site (28.4Bq/Kg), but the least in Tubas- Al'Aqaba 1 site (15.1Bq/Kg). The dissolved radon concentration is the highest in Tubas- Gore Zone 1 site (769.6Bq/m^3), but the least in Tubas- Al'Aqaba 1 site (410.0Bq/m^3).

Table 4.7: Radon concentration (C_{Rn}), Radium concentration (C_{Ra}), and dissolved radon concentration (C_S) in Tubas Governorate.

Site	Sample Code	C_{Rn} (Bq/m^3)	C_{Ra} (Bq/Kg)	C_s (Bq/m^3)
Tubas- Al'Aqaba 1	Uss 1	346.5	15.1	410.0
Tubas- Al'Aqaba 2	Uss 2	426.3	18.6	504.0
Tubas- Gore Zone1	Uss 3	650.4	28.4	769.6
Tubas- Gore Zone2	Uss 4	638.0	27.8	755.0
Min		**346.5**	**15.1**	**410.0**
Max		**650.4**	**28.4**	**769.6**
Average		**515.3**	**22**	**609**

Fig. 4.5 The correlation between radon concentrations with Sites for Tubas

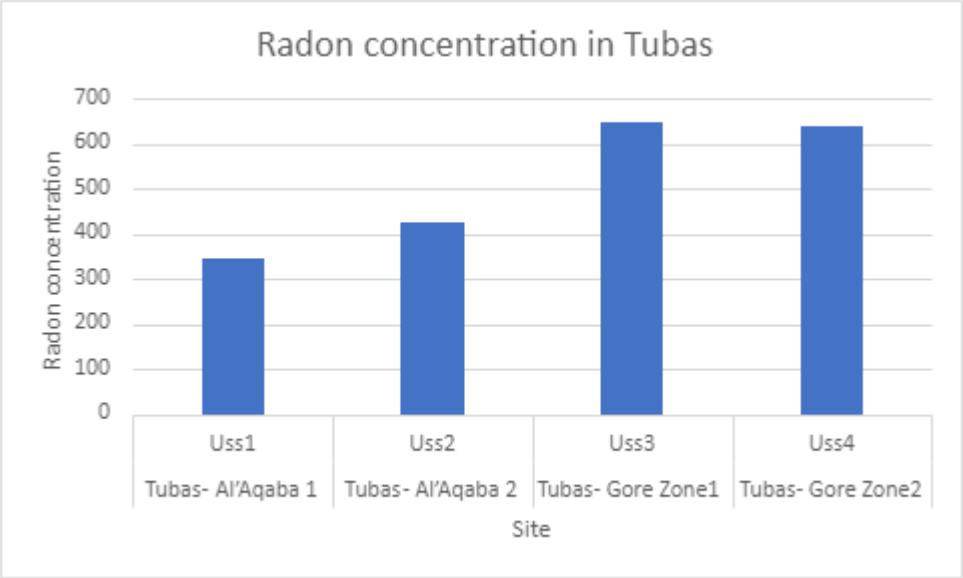


Fig. 4.5 The correlation between radon concentrations with Sites for Tubas

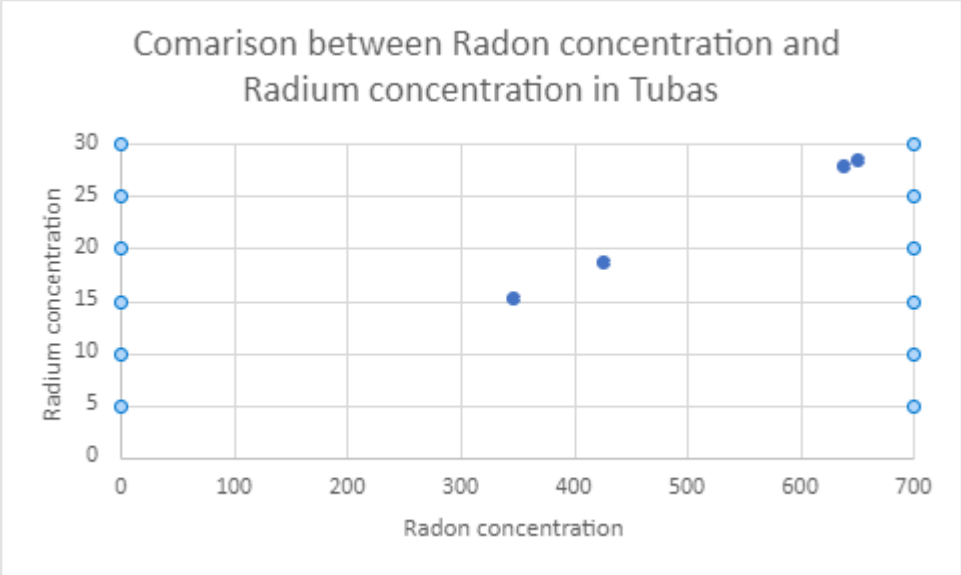


Fig 4.6. The correlation between radium concentrations (C_{Ra}) with radon concentration (C_{Rn}) for Tubas governorate.

Table 4.8, shows the values of the surface and mass exhalation rates of radon for soil samples collected from different sites in the Tubas Governorate. The surface exhalation rate in these collected samples varies from 325.2 $mBqm^{-2}$ h^{-1} (Tubas- Al'Aqaba 1) to 610.5 $mBqm^{-2}$ h^{-1} (Tubas- Gore Zone1 site) with a total average value of 483.67

$mBqm^{-2}\ h^{-1}$. The mass exhalation rate has been found to vary from 7.7 $mBqkg^{-1}\ h^{-1}$ to 14.4 $mBqkg^{-1}\ h^{-1}$ with an average value of 11.45 $mBqkg^{-1}\ h^{-1}$.

Table (4.8): The surface Exhalation Rate (E_A) and the Mass Exhalation Rate (E_M) in Tubas Governorate.

Site	Sample Code	E_A ($mBqm^{-2}h^{-1}$)	E_M ($mBqKg^{-1}h^{-1}$)
Tubas- Al'Aqaba 1	Uss 1	325.2	7.7
Tubas- Al'Aqaba 2	Uss 2	400.0	9.5
Tubas- Gore Zone1	Uss 3	610.5	14.4
Tubas- Gore Zone2	Uss 4	599.0	14.2
Max		**610.5**	**14.4**
Min		**325.2**	**7.7**
Average		**483**	**11**

Table 4.6, shows the values of the annual effective dose, AED_{in}, AED_{out}, and AED_{tot} in Jenin Governorate. The total annual effective dose AED_{tot}, in these soil samples, varies from 12.0 to 22.6 $mSvy^{-1}$ with an average value of 17.8 $mSvy^{-1}$.

Table (4-9): The annual effective dose for indoors (AED_{in}) and outdoors (AED_{out}) and the total annual effective dose (AED_{tot}) in Tubas Governorate.

Site	Sample code	AED_{in} ($mSvy^{-1}$)	AED_{out} ($mSvy^{-1}$)	AED_{tot} ($mSvy^{-1}$)
Tubas- Al'Aqaba 1	Uss1	8.7	3.3	12.0
Tubas- Al'Aqaba 2	Uss2	10.8	4.0	14.5
Tubas- Gore Zone1	Uss3	16.4	6.2	22.6
Tubas- Gore Zone2	Uss4	16.1	6.0	22.1
Min		**8.7**	**3.3**	**12.0**
Max		**16.4**	**6.2**	**22.6**
Average		**13.0**	**4.9**	**17.8**

Table 4.10, shows the average values of radon concentration in soil samples collected from different sites in Palestine. It is seen that the average values of radon concentration in the collected samples vary from 119.8 Bqm^{-3} (in the Nablus region) to 498.5 Bqm^{-3} (in the Tubas region). We notice from the results of the present study that radon concentrations in the three regions are relatively higher than in the other regions in Palestine.

Table 4-10: Comparison of Radon Concentration Levels in soil samples at the present work with those in Palestine.

Site	**Radon Concentration (Bqm^{-3})**			**Ref.**
	Min	Max	Av.	
Bethlehem	19.1	572.9	145.0	Thabayneh, (2018)
Hebron Surface	160.0	425.0	294.0	Thabayneh, 2016
Nablus	76.6	516	274.3	Shoqwara et al,(2013)
Jericho	169.3	6184.4	1388.0	Walid Khalilia et al (2020)
North Gaza	23.5	584.1	207.24	Hamed, 2005
Present work -Tulkarm	281	826.0	505.2	Present work
-Jenin	115.8	745.5	528.0	
-Tubas	346.5	650.4	515.3	

4.3 Discussion

The measurements show higher levels of radon concentration emitted from most soil samples collected from the Tulkarm, Jenin, Tubas region. The levels are higher in samples collected from Illar (Tulkarm region), Salem -middle village 2 (Jenin region), and Al'Aqaba 1 (Tubas region) with other samples collected from other sites. This high concentration maybe because of higher radium and uranium contents in these samples. Then the radon is the main source of radiation in soils and rocks. Other similar

measurements performed by various researchers showed that the soil radon concentration may vary over a wide range dependent on weather conditions, climate factors, and soil type. The gotten results show that the values of radon concentrations of most samples are below the allowed limit from International Commission on Radiological Protection (ICRP). The ICRP recommended that a radon concentration from 200 to 600 Bqm^{-3} for dwellings [65]. The radon levels presented above are more than the new reference level (100 Bqm^{-3}) set by WHO. Hence, the result shows that this area is relatively dangerous as the health risks of radon are concerned.

The presence of the radium in soil samples for this study may be attributed to the variation of uranium concentrations of the soil in regions and the high values in some samples because of its containment to phosphate, granite, sandstone, and quartzite.

The radon exhalation rate from the soil is due to the amount of radium and the porosity of the soil. It is observed that the radon exhalation rate from the soil is bigger than that from building materials [53]. This change is determined by a bigger porosity of the soil. The values of radon exhalation rate were found well low the world average value of 57600 $mBqm^{-2}\ h^{-1}$ (UNSCEAR 2000). Hence it was suggested that for construction purposes this soil may be used, as it does not pose health hazards due to the low radon exhalation rate.

In all the locations under investigation, the most annual effective dose is The values are found to be slightly larger than the action levels (3-10 $mSvy^{-1}$) recommended by ICRP (ICRP 1993) [65]. Moreover, these values seem to be safe from the site of view of health hazards.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Chapter 5- Conclusions and Recommendations

5.1 Conclusions

In this study, the use of a dosimeter cumulative passive containing the solid-state nuclear track detector(SSNTDS) type (CR-39) to estimate the radon concentration, the annual effective dose, the radium concentration, the radon exhalation rate, and the dissolved radon concentration in soil samples collected in the different locations in the northern part of the west bank- Palestine. A total of forty soil samples were collected from the area under investigation to determined and assess the radiological hazards. The total average values of radon concentration for (Tulkarm, Jenin, Tubas) sites were (505, 528, 515) Bq/m^3, respectively. These results indicate a risk to public health due to these high concentrations.

The total average value of the annual effective dose for (Tulkarm, Jenin, Tubas) sites was (17.5, 18.3, 17.8) $mSvy^{-1}$, respectively. The values are found to be slightly larger than the action levels (3-10 $mSvy^{-1}$) recommended by ICRP- 1993.

The values of radium concentration were found to be less than the permissible value of 370 Bq/Kg as recommended by the Organization for Economic Cooperation and Development (OECD), and larger than the global value 30 Bq/Kg by UNSCEAR.

All the values were found to be within risk limits as recommended by ICRP and WHO. Consequently, the health hazards related to radiation are expected to be not negligible.

The measurement obtained stresses the need for a more extended survey on radon risk all over the country. The measurements taken in this study represent a baseline database of activity levels that can serve as a reference point for future studies to indicate impacts from future events. Finally, it must be noted that this work is the first work to be conducted in the soil of the area under investigation, further work is to be conducted to cover other places in different seasons.

5.2 Recommendations

It is advisable not to be established homes in areas that contain a high concentration of radon for the prevention of radiation exposure that leads to cancer morbidity. Radon has been recognized as one of the health hazards for mankind because long-term radon

exposure increases the risk of developing lung cancer. The present work recommends that more investigations are intreated to investigate the radon concentration in other regions in the west bank and to map the radon gas in the soil at the west bank. This would give a good stimulation to remedial the areas of radiation contamination and protect people from radiation risks.

There are many environmental problems affected on soil in the future such as radiation exposure the major cause of radiation exposure is waste factories that flow from these factories towards agriculture.

The method of disposing of solid waste in these illegal factories is done randomly which leads to soil pollution poses an environmental and health hazard to the people so Factories should be set up away from residential areas and waste disposed of in proper ways. Also, more research to discover diseases especially cancer disease.

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