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Measurement of Radon Concentration in Soil at North Gaza

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Thesis

Submitted to faculty of Science as a Partial Fulfillment of the
Master of Science (M.Sc) in Physics

2005

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

”وقل اعملوا فسيرى الله عملكم ورسوله والمؤمنون
وستردون إلى عالم الغيب والشهادة فينبئكم بما كنتم
تعملون“

صدق الله العظيم

سورة التوبة أية (105)

الإهداء

إلى الأرض التي بارك الله فيها ، الأرض المقدسة، أرض الخير والعطاء ومهد
الديانات السماوية . . .

إلى تراب الوطن الغالي

إلى أول كلمتين عرفهما لساني . . . إلى أول من أوصاني الله بهما خيرا . . .
إلى أبي . . . أمي .

إلى الحريصة والصبورة . . إلى الأمينة والغيورة . . وإلى من أعطت مثلاً
بوفائها وعطائها لزوجها وأولادها . . .

زوجتي الغالية .

إلى من رأيت فيهم البراءة بأصدق معانيها . . . إلى من حبهم يجري في دمي.
أبنائي الأحباء

Acknowledgement

My sincere gratitude goes to my supervisors, Prof. M. M. Shabat and Associate Prof. S S. Yassin, for useful discussion, kind help and guidance throughout this work.

Thanks due to many helpful comments and some important advise.

Last but not least many thanks to the staff members of physics Department at Islamic University-Gaza.

I really indebted to the Palestinian Energy Authority and Natural Resources for their encouragement of

scientific research and moral support. I would also like to thank my wife for her patience and kind support during this work as well as to my parents.

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Abstract

Measurement of Radon Concentration in Soil at north Gaza

Solid state nuclear track detectors (CR-39) are used to measure Radon (^{222}Rn) concentration in soil at north Gaza, Palestine. One hundred sixty (160) CR-39 dosimeters with dimension 2x1.5 cm and dosimeter were distributed in five different locations on Gaza {East Beat Hanoun (E BH), West Beat Hanoun (W BH), Al SHaaf (AL SH), East JAbalia (E JA) and Beat Lahia (B L)}.

A hole is digged into the soil of about 11cm in diameter and 50cm in depth. Then 70cm long PVC tube is fixed into the hole, leaving 20cm above the soil surface (with the covered top end of tube sticking out the ground by about 20cm).

At the bottom of each tube a Radon dosimeter is placed. The exposure time for the dosimeters was 60 days during the months September, October and November of 2004 to allow Radon gas to come to an equilibrium level.

The collected detectors were chemically etched using a 6.00 M solution of NaOH, at a temperature of (70 ± 0.2) oC, for 6 hours, (standard etching condition). An optical microscope with a power of (40×10) , manually the number of tracks per cm^2 in each detector where counted. We are measured the average Radon concentration in Bq.m^{-3}

Results obtained that the average value of Radon concentration in soil air at north Gaza was 207.24 Bq/m^3 (5.6pCi/L), ranging from (23.48 – 584.15)

Bq/m³ ((0.64 – 15.79) pCi/L), with value standard deviation 34.90Bq/m³ (0.94 pCi/L).

There were considerable differences between the individual Radon concentration values for each location, for example for AL SH the smallest value was 150.84 Bq/m³ (4.08 pCi/L) and for E JA the largest was 246.22Bq/m³ (6.66 pCi/L). The overall minimum and maximum were 23.48 Bq/m³ (0.64 pCi/L) and 584.15 Bq/m³ (15.79 pCi/L), respectively, which is a difference of almost two orders of magnitude.

Certainly, this study was conducted to provide a health oriented Radon assessment of Gaza strip, and to address long term management goals, especially from the environmental point of view.

CHAPTER

(1)

BACKGROUND RADIATION

1.1 Introduction:

Radiation is the emission of energy as either waves (electromagnetic radiation) or particles (particle radiation). It is produced by radioactive decay, nuclear fission and nuclear fusion, chemical reactions, hot objects, and gases excited by electric currents [1].

Radiation is often separated into two categories, ionizing and non-ionizing, to denote the energy and danger of the radiation. Ionization is the process of removing electrons from atoms, leaving electrically charged particles (ions) behind. Many forms of radiation such as heat, visible light, microwaves, or radio waves do not have sufficient energy to remove electrons from atoms and hence, are called non-ionizing radiation. In the case of heat, for objects at room temperature, most of the energy is transmitted at infra-red wavelengths.

The negatively charged electrons and positively charged nuclei created by ionizing radiation may cause damage in living tissue. The term radioactivity generally refers to the release of ionizing radiation [1].

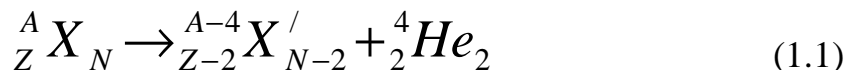
1.2 Types of Radiation:

There are generally four types of radiation associated with radioactive decay:

1.2.1 Alpha particles:

An alpha particle is a positively charged particle emitted in the radioactive decay of some unstable atoms. It consists of two protons and two neutrons (it is essentially the nucleus of a helium atom) and is thus heavier and slower-moving than other decay emissions. Alpha particles do not penetrate far into a material and can be stopped quite easily; however, they are capable of breaking chemical bonds (which can cause chemical or biological damage) when they strike a molecule because of their size, mass and charge. (Penetration distance of alpha particles depends upon the energy with which they are emitted and the material through which they are passing). Thus, while alpha particles can be stopped by thin barriers such as a piece of paper or skin, alpha emitters are mostly damaging if they are ingested or inhaled into the lungs. Uranium (^{238}U), Radium (^{226}Ra) and Radon (^{222}Rn) are typical alpha-particle emitters [2].

α Decay: a nucleus emits an α particle (helium). The decay process is:

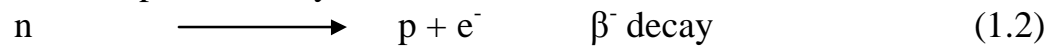


where X and X' are the initial and final nuclei, A is the total mass number, N is the number of neutrons and Z is the number of protons in nucleus.

1.2.2 Beta particles:

A beta particle is emitted during the radioactive decay of some unstable atoms. Beta particles can have either a negative charge or a positive charge and they have the same very small mass (1/2000 the mass of a neutron) regardless of charge [2]. A negatively charged beta particle is called an electron, and a positively charged beta particle is called a positron. Beta particles can penetrate farther than alpha particles (Its penetration distance depends upon the energy of beta particle and material used); however, they can be stopped fairly easily by a sheet of aluminum.

β Decay: here the nucleus can correct a proton or a neutron excess by directly converting a proton into a neutron or a neutron into a proton. These processes can occur in three possible ways [2]:



1.2.3 Electromagnetic radiation:

Two types of electromagnetic radiation are associated with radioactive decay. Electromagnetic radiation is referred to as a gamma ray (this happens when the nucleus transitions from a higher energy level to a lower energy level). Electromagnetic radiation emitted by an atomic electron changing energy levels is referred to as an x-ray. Gamma rays usually have higher energies than x-rays and both can penetrate matter farther than any particles. They can be stopped by high density materials such as several feet of concrete or lead [2].

1.2.4 Neutrons:

Neutrons are particles having a mass 1/4 that of an alpha particle and 2000 times that of a beta particle. The neutron has no electrical charge. It has the potential to penetrate matter deeper than any other charged particles but this depends greatly on the physical and atomic nature of the matter being penetrated [2].

1.3 **Radioactive Decay:**

Radioactive materials have an associated half-life, or decay time characteristic of that isotope. As radiation is emitted, the material becomes less radioactive over time, decaying exponentially [3].

Some radioisotopes have long half-life's; for example, ^{14}C takes 5,730 years for any given quantity to decay to half of the original amount of radioactivity. Other radioactive materials have short half-lives; ^{32}P has a two week half-life, and ^{99}Tc (used in human and animal nuclear medicine diagnostic procedures) has a half-life of 6 hours [4].

The equation which is used to calculate radioactive decay is shown below.

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

Where:

A = Current amount of radioactivity

A_0 = Original amount of radioactivity

e = base natural log ≈ 2.718

λ = Disintegration constant or decay constant = $0.693/t_{1/2}$ (where $t_{1/2}$ = half-life)

t = the amount of time elapsed from A_0 to A . It is important to be careful of the units used for the time. Days, hours and years must not be mixed in the calculation [4].

1.4 Sources of Radiation.

Naturally occurring radioactive materials are common in the environment and in the human body. These materials are continuously emitting ionizing radiation. Ionizing radiation from outer space (cosmic radiation) bombards the earth constantly. Collectively, the ionizing radiation from these and similar sources is called background radiation. Human activities, such as making medical x-rays, generating nuclear power, testing nuclear weapons, and producing smoke detectors which contain radioactive materials, cause additional exposure to ionizing radiation. The sources of radiation can be classified into natural and man-made radiation.

The percentage of the average annual radiation exposure contributed by each major source is illustrated in Figure 1. About 82 percent is from nature, and 18 percent is from industrial, medical, and consumer sources. The values given in Figure 1.1 are averages for the United States. Actual values vary depending on where people live and how they spend their time [5].

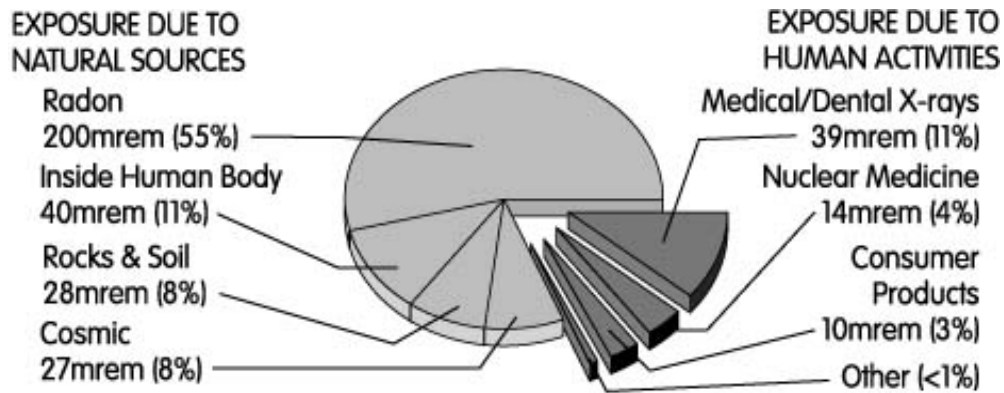


Figure 1.1: Average Annual Exposure to Ionizing Radiation (1Sv = 100rem)

Table 1.1: indicates that Radon and its daughters contribute the maximum percentage of annual effective dose equivalent. These numbers are average and were obtained by estimating the total dose for the U.S., and dividing by number of people in the U.S. [6].

Table 1.1: Annual Effective Dose Equivalent.

| Sources | Dose (mrem/yr) | Percent of Total |
|------------------------------|----------------|------------------|
| Natural radiation | | |
| Radon | 200 | 55% |
| Cosmic | 27 | 8% |
| Terrestrial (Rocks and Soil) | 28 | 8% |
| Internal (Inside Human Body) | 40 | 11% |
| Total natural | 295 | 82% |
| Man-made radiation | | |
| Medical X-Ray | 39 | 11% |
| Nuclear medicine | 14 | 4% |
| Consumer products | 10 | 3% |
| Other | | |
| Occupational | 0.9 | < 0.3% |
| Nuclear fuel cycle | <1 | <0.03% |
| Fallout | <1 | <0.03% |
| Miscellaneous | <1 | <0.03% |
| Total artificial | 65 | 18% |
| The Total | 360 | 100% |

1.4.1 Natural Radiation Sources

1.4.1.1 Primordial Radionuclides Sources

Primordial radionuclides sources include naturally occurring radioactive materials that exist in rocks, **soil**, water, and **vegetation**. The major isotopes of concern for primordial radionuclides radiation are uranium and its decay products, such as thorium, radium, and **Radon**. Some of these materials are ingested with food and water, while others, such as Radon, are inhaled.

The dose from primordial radionuclides sources varies in different parts of the world. Locations with higher concentrations of uranium and thorium in their soil have higher dose levels [7].

These primordial radionuclides are left long time ago. They are typically long lived, with half-lives often on the order of hundreds of millions of years. Radionuclides that exist for more than 30 half-lives are not measurable. The progeny or decay products of the long lived radionuclides are also in this heading. Here is some basic information on some common primordial radionuclides: [6].

Table 1.2: Primordial Nuclides

| Nuclide | Symbol | Half-life | Natural Activity |
|--------------|-------------------|-------------------------------|--|
| Uranium 235 | ²³⁵ U | 7.04 x 10 ⁸ yr | 0.72% of all natural uranium |
| Uranium 238 | ²³⁸ U | 4.47 x 10 ⁹ yr | 99.2745% of all natural uranium; 0.5 to 4.7 ppm total uranium in the common rock types |
| Thorium 232 | ²³² Th | 1.41 x 10 ¹⁰ yr | 1.6 to 20 ppm in the common rock types with a crustal average of 10.7 ppm |
| Radium 226 | ²²⁶ Ra | 1.60 x 10 ³ yr | 0.42 pCi/g (16 Bq/kg) in limestone and 1.3 pCi/g (48 Bq/kg) in igneous rock |
| Radon 222 | ²²² Rn | 3.82 days | Noble Gas; annual average air concentrations range in the US from 0.016 pCi/L (0.6 Bq/m ³) to 0.75 pCi/L (28 Bq/m ³) |
| Potassium 40 | ⁴⁰ K | 1.28 x 10 ⁹ yr | soil - 1-30 pCi/g (0.037-1.1 Bq/g) |

The primordial radionuclides of the decay chain of those radioactive materials are presented in Appendix(I)

1.4.1.2 Cosmic Radiation

Charged particles from the sun and stars interact with the earth's atmosphere and magnetic field to produce a shower of radiation. The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field [7].

Cosmic radiation is really divided into two types, primary and secondary.

▼ Primary cosmic radiation:

Primary cosmic radiation is made up of extremely high energy particles (up to 10¹⁸ eV), and are mostly protons (87%), with some larger particles (alpha radiation 12%). A large percentage of it comes from outside of our solar system and is found throughout space. Some of the primary cosmic radiation is from our sun, produced during solar flares [7].

Some of the primary cosmic radiation penetrates to the Earth's surface, the vast majority of it interacts with the atmosphere. These reactions produce other lower energy radiations in the form of photons, electrons, neutrons and muons that make it to the surface.

▼ Secondary cosmic radiation

- Results from the interaction of primaries with the earth's atmosphere
- Cascade effect: one primary ionization = 100 million secondary ionizations
- Products produced: pions, muons, electrons, photons, protons, neutrons
- Primaries absorbed within the upper 10% of the atmosphere
- Dominant components at ground level are penetrating muons and the electrons they produce.
- Latitude contributes a small factor due to the earth's magnetic field.

The atmosphere and the Earth's magnetic fields also act as shields against cosmic radiation, reducing the amount that reaches the Earth's surface [7].

1.4.1.3 Cosmogony Radiation

Cosmic radiation permeates all of space, the source being primarily outside of our solar system. The radiation is in many forms, from high speed heavy particles to high energy photons and muons. The upper atmosphere interacts with many of the cosmic radiations, and produces radioactive nuclides. They can have long half-lives, but the majority have shorter half-lives than the primordial nuclides. Here is a table with some common cosmogenic nuclides:

Table 1.3: Cosmogenic Nuclides

| Nuclide | Symbol | Half-life | Source | Natural Activity |
|-------------|-----------------|------------|--|---|
| Carbon 14 | ^{14}C | 5730 yr | Cosmic-ray interactions, $^{14}\text{N}(n,p)^{14}\text{C}$; | 6 pCi/g (0.22 Bq/g) in organic material |
| Tritium 3 | ^3H | 12.3 yr | Cosmic-ray interactions with N and O; spallation from cosmic-rays, $^6\text{Li}(n,\alpha)^3\text{H}$ | 0.032 pCi/kg (1.2 x 10 ⁻³ Bq/kg) |
| Beryllium 7 | ^7Be | 53.28 days | Cosmic-ray interactions with N and O; | 0.27 pCi/kg (0.01 Bq/kg) |

1.4.1.4 The Radon

The largest natural source of radiation exposure to humans is radon gas, that exist on air, water and soil. While radon gas has always been in the environment, its contribution to human radiation exposure has increased in recent years. Radon's primary pathway is from the earth, through the basements of houses and other buildings, and into inside air that people breathe. Radon exposures can vary depending on the soil and rock structure beneath buildings. To conserve energy, buildings are more tightly constructed so there is less exchange of inside air with fresh air from outside. This tends to trap radon inside [5].

The Radon concentration in soil is our main concern in the presented work and will be discussed in detail in proceeding chapters.

1.4.1.5 Internal Radiation

Internal radiation comes from radioactive materials that occur naturally in the human body. Potassium and Carbon are the primary sources of internal radiation exposures.

Potassium is an essential mineral for life. The Potassium (^{40}K) isotope (0.01 percent of all potassium) is naturally radioactive. It enters the human body through the food chain. Carbon makes up about 23 percent, by weight, of the human body. Cosmic radiation creates Carbon (^{14}C), which is a small percentage of all carbon. Carbon enters the body both through the food chain and by breathing [5].

1.4.2 **Man-Made Radiation Sources**

Natural and artificial radiation sources are identical in their nature and their effect. By far, the most significant source of man-made radiation exposure to the general public is from medical procedures, such as diagnostic

X-rays, nuclear medicine, and radiation therapy. Some of the major isotopes would be ^{131}I , ^{99}Tc , ^{60}Co , ^{192}Ir , ^{137}Cs , and others.

In addition, members of the public are exposed to radiation from consumer products, such as tobacco (polonium ^{210}Po), building materials, combustible fuels (gas, coal, etc.), ophthalmic glass, televisions, luminous watches and dials (tritium), airport X-ray systems, smoke detectors (americium), road construction materials, electron tubes, fluorescent lamp starters, lantern mantles (thorium), etc [7].

Occupationally exposed individuals are exposed according to their occupations and to the sources with which they work. The exposure of these individuals to radiation is carefully monitored with the use of pocket-pen-sized instruments called dosimeters. Some of the isotopes of concern would be cobalt (^{60}Co), cesium (^{137}Cs), americium (^{241}Am), and others [7].

Examples

of industries where occupational exposure is a concern include:

- Fuel cycle
- Industrial Radiography
- Radiology Departments (Medical)
- Radiation Oncology Departments
- Nuclear power plant
- Nuclear medicine Departments
- National (government) and university Research Laboratories

It is known that the background level of radiation exposure, the NRC requires that its licensees limit man-made radiation exposure to individual members of the public to 100 mrem (1 mSv) per year, and limit occupational radiation exposure to adults working with radioactive material to 5,000 mrem (50 mSv) per year.

The exposure for an average person is about 360 millirems/year (360mrem=3.6mSv), 81 percent of which comes from natural sources of radiation. The remaining 19 percent results from exposure to man-made radiation sources.

1.5 Units of Radiation Measurement

Two types of units are used for radiation, units of *activity* and units of *exposure* (dose). Units of activity quantify the amount of radiation emitted by a given radiation source. Units of exposure quantify the amount of radiation absorbed or deposited in a specific material by a radiation source.

In the world today, two sets of units exist. They are the special units (*Curie, Roentgen, Rad and Rem*) and the SI or International Units (*Becquerel, Gray and Sievert*) [4].

1.5.1 Activity

The *Activity* A of a radioisotope sources is defined as its rate of decay and is given by the fundamental law of radioactive decay

$$A = \left(\frac{dN}{dt}\right)_{decay} = -\lambda N \quad (1.6)$$

where N is the number of radioactive nuclei and λ is defined as the decay constant.

The historical unit of *activity* has been the *curie* (Ci), originally defined as the amount of radioactive material emitting 3.7×10^{10} disintegrations (particles or photons) per second (DPS).

The *becquerel* (Bq), which is 1 disintegration per second, is the SI unit for activity.

$$1Ci = 3.7 \times 10^{10} Bq \quad (1.7)$$

Radioactive sources of convenient size in the laboratory are more reasonably measured in kilobecquerels (kBq) or megabecquerels (MBq) [8].

1.5.2 Exposure:

It is the being exposed to ionizing radiation or radioactive material. The special unit of exposure is the *Roentgen*.

Roentgen (R) is the quantity of X- or gamma radiation needed to produce **1esu** (electrostatic **unit**) of ionic charge in one cubic centimeter of dry air at **STP** (Standard Temperature and Pressure). The roentgen, however, is limited to use with X- or gamma radiation with energy less than 3 Mev [9].

$$1R = \frac{1esu}{cm^3 air} \quad (1.8)$$

where

$$1esu = \frac{1}{3 \times 10^9} coulomb \quad (1.9)$$

One Roentgen is equal to the quantity of gamma or x-radiation that will produce ions carrying a charge of 2.58×10^{-4} coulombs per kilogram of air.

$$1R = \frac{1 \times \frac{1}{3 \times 10^9}}{0.001293} = 2.58 \times 10^{-7} \frac{\text{Coulomb}}{\text{gram}}$$

Or

$$1R = 2.58 \times 10^{-4} \frac{\text{Coulomb}}{\text{kg}} \quad (1.10)$$

An exposure to one *Roentgen* of radiation with total absorption will yield 89.6 ergs of energy deposition per gram of air [4]. The *Roentgen* is easy to measure with an ion chamber, an instrument that will measure the ions (of one sign) produced in air by the radiation. The ion chamber has a readout in *Roentgen* per hour or fractions thereof, and is an approximation of tissue exposure.

The Radiation Absorbed Dose (rad) and the Radiation equivalent man (rem) are the two main radiation units used when assessing radiation exposure [4].

1.5.2.1 Radiation Absorbed Dose (rad):

Absorbed Dose is the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The fundamental dosimetric quantity D , defined as: [9].

$$D = \frac{de}{dm} \quad (1.11)$$

where de is the mean energy imparted by ionizing radiation to matter in a volume element dm . The unit of absorbed dose is the *rad* which is the amount of absorbed radiation that deposits 100 ergs per gram or 0.01 J per kilogram of material [9].

1.5.2.2 Radiation equivalent man (rem).

The rem (radiation equivalent man) is the unit of human exposure and is a equivalent dose (H). (The international or SI unit for human exposure is the Sievert, which is defined as equal to 100rem.) It takes into account the biological effectiveness of different types of radiation. The target organ is important when assessing radiation exposures and a modifying factor is used

in radiation protection to correct for the relative biological effectiveness. Also, the chemical form of the radiation producing the dose is of critical importance in assessing internal doses, because different chemicals bind with different cell and/or organ receptor sites [4].

Additionally, some types of radiation cause more damage to biological tissue than other types. For example, one rad of alpha particles is twenty times more damaging than one rad of gamma rays [4].

Typical values of the Radiation Weighting Factor are given below in Table 1.4 [9].

Table 1.4: Radiation Weighting Factor (W_R) with Different Radiation

| Types of Radiation | Radiation Weighting Factor W_R |
|------------------------------------|----------------------------------|
| X- or γ -rays | 1 |
| Electron (β) | 1 |
| Neutrons | |
| Neutrons <10 keV | 5 |
| Neutrons (10keV-100 keV) | 10 |
| Neutrons (100keV-2000 keV) | 20 |
| Neutrons (2MeV- 20MeV) | 10 |
| Neutrons > 20MeV | 5 |
| protons < 2MeV | 10 |
| α -particles and heavy ions | 20 |

To account for these differences, a unit called a Radiation Weighting Factor W_R is used in conjunction with the radiation absorbed dose in order to determine the *equivalent dose*. The unit of equivalent dose is $J.kg^{-1}$, termed the sievert (Sv) { 1Sv = 100rem} [10].

$$H_T = \sum_R W_R \cdot D_{T,R} \quad (1.12)$$

where

H_T : Equivalent Dose,

W_R : radiation weighting factor for radiation R

$D_{T,R}$: Average absorbed dose by radiation type R in the organ or tissue T

Tissue weighting factors, W_T , are used for incorporating the actual risk to tissues for different radioisotopes and tissues in dose calculations. These weighting factors assign multiplication factors for increasing or decreasing the actual biological risk to a given tissue. Typical values of the Tissue Weighting Factor W_T are given below in Table(1.5) [9].

Table 1.5: Tissue Weighting Factor W_T with Tissue or Organs for Human Body.

| Tissue or organ | Tissue Weighting Factor W_T |
|--|-------------------------------|
| Gonads | 0.2 |
| Bone marrow | 0.12 |
| Colon | 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 |
| Pancreas, small intestine, uterus, brain, spleen, muscle, suprarenal gland, kidney, thymus gland | 0.01 |

The Effective Dose E is defined as summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor [10].

$$E = \sum_T W_T \cdot H_T \quad (1.13)$$

where H_T is the equivalent dose in tissue T and W_T is the tissue weighting factor for tissue T , from the definition of equivalent dose, it follows that [10].

$$E = \sum_T W_T \cdot \sum_R W_R \cdot D_{T,R} \quad (1.14)$$

where W_R is the radiation weighting factor for radiation R . The unit of effective dose is J.kg^{-1} , termed the sievert (Sv) {1Sv = 100rem} [10].

1.6 Health Effects of Ionizing Radiation

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

Effect of radiation: Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms,

forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage.

At low doses, such as what we receive every day from background radiation, the cells repair the damage rapidly. At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Cells changed permanently may go on to produce abnormal cells when they divide. In the right circumstance, these cells may become cancerous. This is the origin of our increased risk in cancer, as a result of radiation exposure [11]. Prolong exposure to the radiation would certainly cause health risks.

1.7 Objectives

Many scientific researchers have debated the effects of ionizing radiation on human health.

Public exposure to Radon and its daughters present in the environment results in the largest contribution to the average effective dose received by human beings [13]. Under specific conditions, such as those existing in the Uranium mining environment, the lung dose arising from the inhalation of Radon daughters can be sufficiently high as to cause an increase in lung cancer occurrence [14].

We believe, several environmental problems currently affect the Gaza Strip. These problems have not received serious investigation. Practically, exposures to radiation materials may be represent one of these environmental problems. A previous study of Radon concentration in air (Indoor and outdoor) of Gaza strip was conducted by M. Rassas (2003). The concluded results shown the average Radon concentration was 37.83 Bq/m^3 with average standard deviation of 11.23 Bq/m^3 . Therefore we have proposed to investigate the Radon concentration in different area in soil of Gaza. Soil along the coast of the Gaza Strip may contain elevated concentration of some of the radioactive minerals, like uranium and thorium, which are derived from the granite sources rocks present in the area. The main interest of the present work is to investigate this effect of radiation and how to measure its concentrations.

1.8 Scope

This research program aims to study a preliminary survey of Radon concentration in soil at north Gaza strip. This study will enable us to identify the environmental problem concerning radiation hazards.

A passive diffusion Radon dosimeter containing CR-39 solid state nuclear track detectors (SSNTDs) will be used in this survey. These dosimeters were distributed in soil that selected in the north Gaza, **East Biet Hanoun (E BH)**, **West Biet Hanoun (W BH)**, **Al Shaaf (AL SH)**, **East JAbalia (E JA)** and **Biet Lahia (B L)**.

This distribution of the detectors is based on the nature of the soil type and geographical location, see Appendix (III). The detectors are left about 60 days during the months September, October and November of 2004.

In additional, the study aims to measure continuously the Radon concentration in soil and to understand the nature of soil of Gaza strip. Certainly, this study also enable us to identify the factors that affecting Radon concentration in soil in different areas and to find out the methods of remediation.

CHAPTER

(2)

**RADON CONCENTRATION AND
ITS DECAY PRODUCTS**

2.1 Introduction:

The element of Radon (^{222}Rn) was discovered in 1900 by Dorn, who called it radium emanation. It is essentially inert and occupies the last place in the zero groups of gases in the Periodic Table. Since 1923, it has been called Radon. It is estimated that every square mile of soil to a depth of 6 inches contains about 1 g of radium, which releases Radon in tiny amounts into the atmosphere [15]. On the average, one part of radon is present to 1×10^{21} part of air. The main hazard is from inhalation of the element and its solid daughters which are collected on dust in the air [15].

The Radon potential for a given region is likely to be the result of a combination of properties of the underlying rocks and of the soil, such as the distribution of uranium and radium, porosity, permeability, and moisture content, as well as meteorological and seasonal variation. such as atmospheric pressure, temperature, CO_2 concentration in the soil, and so on [16].

2.2 Characteristics of Radon and its decay product's:

2.2.1 Radon:

Radon is a mobile, chemically inert radioactive element. Its atomic number of 86 makes it a noble element and therefore both non-reactive chemically and atomically mobile at normal temperatures [17]. Radon is the heaviest noble gas and exhibits the highest boiling point, melting point, critical temperature, and critical pressure of all noble gases. Radon is highly soluble in nonpolar solvents and moderately soluble in cold water [18].

Radon is a natural radioactive gas produced by the natural radioactive decay of uranium and thorium. Both uranium and thorium are ubiquitous in the ground and the important isotopes are ^{238}U and ^{232}Th [19]. The decay chains for both these nuclides are given in Appendix (I) and Appendix (II).

The levels of uranium and thorium present depend on local geology. The three naturally isotopes produced from radium decay as steps in lengthy sequences of decays that originate from uranium or thorium isotopes - ^{222}Rn (called Radon), from ^{238}U , has a half-life of 3.823 days and is an alpha emitter; ^{220}Rn (called thoron) emanating naturally from thorium and has a half-life of 55.6 s and is also an alpha emitter. ^{219}Rn (called action) emanates from actinium and it has a half-life of 3.96s and is also an alpha emitter [20]. However, our concern in the present work is to measure Radon (^{222}Rn) concentration in soil air.

2.2.2 Decay Products of Radon (^{222}Rn):

Radon decay products is another name for the Radon progeny or Radon daughters. Radon decay products rather than Radon gas deliver the actual radiation dose to lung tissues [18].

The Radon decay products are radioactive isotopes of Polonium, Bismuth, Lead, and thallium. Which are produced by decay of the Radon isotopes. These daughters of the radioactive gases are isotopes of heavy metals and are easily fixed to existing aerosol particles in the atmosphere. They decay by alpha particles and beta / gamma emission.

Radon decay products are divided into two groups: the "**short-lived**" Radon daughters ^{218}Po (3.05 min), ^{214}Pb (36.8 min), ^{214}Bi (19.7 min), ^{214}Po (164 μSv) with half – lives below 30 min, and the "**long-lived**" Radon decay products ^{218}Po (22.3 years), ^{210}Bi (5.01 days), ^{210}Po (138.4 days), as show in Table 2.1.

Table 2.1: Uranium and Thorium Series:

Uranium Series:

| A/A | Nucleus | Half-live | Energy (Mev) | Radiation type |
|-----|-------------------|--------------------------|-----------------------|---------------------|
| 1. | ^{238}U | 4.51×10^5 Years | 4.2 (75%) | α |
| 2. | ^{234}U | 2.47×10^5 Years | 4.77 (72%) | α |
| 3. | ^{234}Ac | 24 Days | 0.100, 0.192 0.09 | β γ |
| 4. | ^{230}Th | 8.0×10^4 Years | 4.68 (76%) | α |
| 5. | ^{226}Ra | 1602 Years | 4.68 (95%) | α |
| 6. | ^{222}Rn | 3.82 Days | 5.49 (100) | α |
| 7. | ^{218}Po | 3.05 min | 6.00 (100%) | α |
| 8. | ^{214}Bi | 19.7 min | 3.26, 1.5, 1.00 | β |
| 9. | ^{214}Po | 016 msec | 7.69 (100%) | α |
| 10. | ^{210}Pb | 22 Years | 0.015, 0.065 0.065 | β γ |
| 11. | ^{210}Bi | 5 Days | 1.17 | β |
| 12. | ^{210}Po | 138 Days | 5.30 (100%) | α |
| 13. | ^{206}Pb | Stable | | |

Thorium Series:

| A/A | Nucleus | Half-live | Energy (Mev) | Radiation type |
|-----|-------------------|----------------------------|------------------------|----------------------|
| 1. | ^{232}Th | 1.4×10^{10} Years | 3.95 (76%) 0.055 | α γ |
| 2. | ^{228}Ra | 6.7 Years | 0.055 | β |
| 3. | ^{228}Ac | 6.13 Years | 2.18, 1.85, 1.11, 1.72 | β |
| 4. | ^{228}Th | 1.91 Years | 5.68 (71%) | α |

| | | | | |
|----|-------------------|------------|---------------------------------|---------------------|
| 5. | ^{224}Ra | 3.64Days | 5.68 (94%) | α |
| 6. | ^{220}Rn | 55 s | 6.29 (100%) | α |
| 7. | ^{216}Po | .015s | 6.79 (100%) | α |
| 8. | ^{212}Pb | 10.6 hours | 0.57, 0.33 0.3, 0.238, 0.178 | β γ |
| 9. | ^{212}Bi | 60sec | 2.23 | β |
| 10 | ^{212}Po | 304 ns | 8.78 (100%) | α |
| 11 | ^{208}Tl | 3.1 min | 1.8 | β |
| 12 | ^{208}Pb | Stable | | |

2.2.3 Behavior of decay products

The overall concentration of decay products is represented by the potential alpha energy concentration (PAEC). It depends on the concentration of the first three decay products (^{218}Po , ^{214}Pb and ^{214}Bi) and on the amount of polonium α energy that obtained. The behavior of Radon daughter is of high interest among scientists not only to satisfy a relationship between indoor Radon concentration and decay product concentration but also to provide a view of decay products exposures [19].

The decay products can attach to aerosol particles, indoor walls, furniture and the human lung if the Radon is inhaled. After the decay of Radon, the daughters can deposits on surface before or after attachment to the particles. The health significance of the decay products is greatly influenced by their half-life decay modes and their behavior after decay [19].

The formation and growth of radon daughter aerosols is illustrated by Figure 2.1: [21,22].

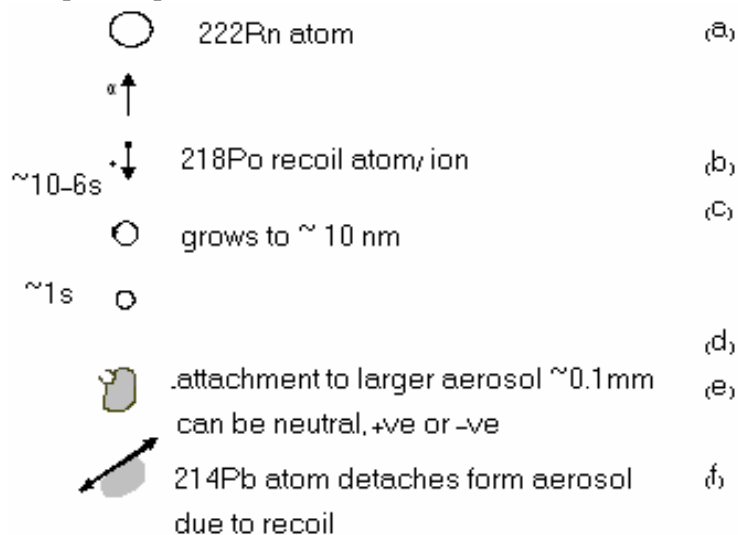


Figure 2.1: Diagrammatically the Formation and Growth of Radon Daughter Aerosols:

- a) The initial Radon (^{222}Rn) atom.
- b) Is an electrically neutral gas atom which is unaffected by electric fields. When Radon decays it emits an alpha-particle (alpha radiation) but at the same time the so-called daughter nucleus of atom, ^{218}Po , recoils.
- c) In doing so it cannot take all of its atomic electrons with it and as a result the daughter atom carries a net positive charge i.e. it is a positively charged ion. Chemically this is a ^{218}Po ion, an isotope of polonium. Within 10^{-6} seconds this ion attracts trace water molecules and gases in air growing to a size of ~ 10 nm.
- d) Such small particles are termed 'ultrafine aerosols'. Within one second the initial positive charge is lost, so resulting in a neutral aerosol.
- e) This aerosol may (or may not) then go on to attach itself to larger aerosols in room air of size range typically 0.1 to 0.2 μm . these are then said to be 'attached radon daughter'. These larger aerosols may pick up stray positive or negative charges, so their charge state (+ve, -ve, or neutral) can vary.
- f) Each ^{218}Po atom is itself alpha-radioactive and has a mean lifetime of 4.4 minutes. When this decay the above process (a) to (e) is repeated i.e. the daughter nucleus from the decay of ^{218}Po , an aerosol becoming a positively charged ^{214}Pb atom or ion.

The concentration of Radon in air is measured in units of picocuries per liter (pCi/L) or (Bq/m^3), with ($1\text{pCi}/\text{L} = 37\text{Bq}/\text{m}^3$). One Bq corresponds to one disintegration per second. The concentration of Radon daughters is measured in units of working level (WL). One WL correspond to 101.3 pCi/L of Radon equilibrium with its short-lived daughter in a typical indoor environment [23].

2.3 Radon Concentration in Soil at Different Countries

Many scientists have given serious attention to study Radon concentration in air, however less attention has been paid to measure the Radon concentrations in soil. In the following section we will discuss the measurements of Radon concentration in soil in different countries providing the method and some of the results.

John F. DeWild and James T. Krohelski [24] have studied Radon concentrations in 29 ground-water samples collected from the sand and gravel and sedimentary and crystalline bedrock aquifers. They are found that Radon range from 260 to $22,000$ pCi/L with a median concentration of 560 pCi/L. The highest Radon concentrations were found in ground water

from wells in Wisconsin. The results were obtained by using the scintillation counter with Lucas cells method [24].

This method is also used to map the geogenic Radon potential in Germany [25]. The results show that Radon concentration in soil is subdivided into categories of low ($< 10 \text{ kBq/m}^3$) – medium ($10 \text{ kBq/m}^3 - 100 \text{ kBq/m}^3$) – increased ($100 \text{ kBq/m}^3 - 500 \text{ kBq/m}^3$) and high ($>500 \text{ kBq/m}^3$) Radon concentration in soil gas.

The influence of the vegetation on the Radon potential is discussed controversially by [26] in Germany.

This study shows a marked influence on Radon concentration in soil gas by vegetation cover. Especially trees can lower the Radon concentration in soil gas significantly. Scintillation counter with Lucas cells method is also used and found the Radon activity concentration increases with increasing distance from the tree. A background level of about 5 Bq/L is reached in a distance $>10 \text{ m}$. again, the Radon activity concentration decreases by approaching the tree the background value drops from 12 Bq/L to 6 Bq/L .

A compilation and evaluation of important parameters of soil Radon potential are also studied by [27] in Germany.

Where a guideline for the evaluation of the soil Radon potential based on geogenic and anthropogenic parameters. Measurements present new insight into geogenic and anthropogenic parameters on the soil. Scintillation counter with Lucas cells method is also used to detect the Radon concentration in soil at depth 80 cm of different types of made ground. Result: Radon concentrations in soil was medium of made ground 9 Bq/L and medium of undisturbed and turbed soil was 43 Bq/L

A Study of Radon Concentration in the Soil and Air of some Villages in Irbid Governorate is described by Karim [28].

He found that the average Radon concentration in soil air of study area at depth 50 cm was about 1221.1 Bq/m^3 . Hubras soil was characterized by the lowest average 1033.4 Bq/m^3 , while Al-Rafeed soil was characterized by the highest average 1557.6 Bq/m^3 . The results obtained by passive closed can technique implying solid state nuclear track detector (SSNTD) CR-39 dosimeter method.

Measurement of Radon Concentration in Soil is also described by [30] where passive closed technique implying solid state nuclear track detector (SSNTD) CR-39 was used. A study found that the average Radon concentration in soil air at west area on Libya coastal sand samples was about 6.997 Bq/m^3 . Sarman soil was characterized by the lowest average 4.70 Bq/m^3 , while Tajoraa soil was characterized by the highest average 9.20 Bq/m^3 .

2.4 Radon in Soil, Water and Air

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

2.4.1 Radon in Soil:

Radon forms in rocks and soil that contain uranium or thorium. Rocks have generally been thought to be the major source, Radon production and migration in soil and bedrock define radon availability, while specific site and construction characteristics control the Radon transfer into houses [31].

Radon moves into houses because of a negative pressure differential, and because of a large concentration gradient between the (house) building and bedrock or soil. The Radon concentration in houses is likely to relate fairly closely to that in the soil although there is no well established method of estimating Radon levels in individual dwellings based on soil Radon data. There are direct correlations between uranium, radium, Radon in soil gas, and indoor Radon concentrations. Reimer *et al.* (1991) also suggested that geology and soil gas Radon are useful indicators of indoor Radon concentration [32].

We considered that soil Radon might provide a reasonable guide for assessing the potential for large Radon concentrations in homes. ^{222}Rn and, ^{220}Rn , are usually produced in approximately equal quantities, but the latter is often ignored because its contribution to the overall dose of radiation is relatively small. For both the soil and buildings there are many other factors, in addition to the spatial variation in the source elements, that complicate the spatial variation of Radon emanation. For example, the spatial variation in soil permeability, porosity, CO_2 concentration in the soil gas, moisture content, and atmospheric pressure affect its emanation. Soil moisture content can increase Radon emanation but, if the soil pores become saturated, emission is inhibited. Carbon dioxide acts as a carrier gas for radon in soil which can enhance its concentration in the soil atmosphere [27].

The values inside buildings depend on structural characteristics, ventilation rates, aerosol concentration, central heating, building materials, and the habits of the inhabitants [16].

2.4.2 Radon in water

Radon can enter home through water systems. Water in rivers and reservoirs usually contains very little Radon, because it escapes into the air; so homes that rely on surface water usually do not have a Radon problem from their water. In big cities, water processing in large municipal systems aerates the water, which allows Radon to escape, and also delays the use of water until most of the remaining Radon has decayed.

In many areas, ground water is used as the main water supply for homes and communities. Small public water works and private domestic wells often have closed systems and short transit times that do not remove Radon from the water or permit it to decay. This Radon escapes from the water to the indoor air as people take showers, wash clothes or dishes, or otherwise use water. A very rough rule of thumb for estimating the contribution of Radon in domestic water to indoor air Radon is that house water with 10,000 pCi/L of Radon contributes about 1 pCi/L to the level of Radon in the indoor air.

The areas most likely to have problems with Radon in ground water are areas that have high levels of uranium in the underlying rocks. For example, granites in various parts of the United States are sources of high levels of Radon in ground water that is supplied to private water supplies. In areas where the main water supply is from private wells and small public water works, Radon in ground water can add Radon to the indoor air[33].

2.4.3 Radon in Air.

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

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

Radon moves into the disturbed zone and the gravel bed underneath from the surrounding soil. The backfill material in the disturbed zone is commonly rocks and soil from the foundation site, which also generate and release Radon. The amount of Radon in the disturbed zone and gravel bed depends on the amount of uranium present in the rock at the site, the type

and permeability of soil surrounding the disturbed zone and underneath the gravel bed, and the soil's moisture content [33].

Radon levels in outdoor air, indoor air, soil air, and ground water can be very different. Outdoor air ranges from less than 0.1 pCi/L to about 30 pCi/L, but it probably averages about 0.2 pCi/L. Radon in indoor air ranges from less than 1 pCi/L to about 3,000 pCi/L, but it probably averages between 1 and 2 pCi/L. The amount of Radon dissolved in ground water ranges from about 100 to nearly 3 million pCi/L [33].

Radon in soil air (the air that occupies the pores in soil) ranges from 20 or 30 pCi/L to more than 100,000 pCi/L; most soils in the United States contain between 200 and 2,000 pCi of Radon per liter of soil air, (The National Average of Approximately 10kBq/m³ (270pCi/L) [33].

Table 2.2: Radon Levels in Outdoor Air, Indoor Air, Soil Air, and Ground Water can be Very Different.

| A/A | Radon levels | Ranges of Radon concentration | Average of Radon Concentration |
|-----|--------------------------|---|--------------------------------|
| 1. | Outdoor air | 0.1pCi/L ---30pCi/L | 0.2pCi/L |
| 2. | Indoor air | 1pCi/L --- 3,000pCi/L | (1-2)pCi/L |
| 3. | Ground water | 100pCi/L --- 3Milion pCi/L | |
| 4. | Soil air United State | 20pCi/L --- 100pCi/L 200pCi/L --- 2,000pCi/L | (20-30)pCi/L |

2.5 The Geogenic and Anthropogenic Parameters Affecting of The Soil Radon Concentration.

Soil is defined as a complex mixture of crumbled rock, organic matter, moisture and gases that varies in texture and composition. Soil is formed by a combination of physical, chemical and biological processes. These include rain and flooding, gravity, wind, radiation, temperature changes and the collective labours of various soil organisms, which recycle decayed plant and animal product into the molecular building blocks necessary for creating new life.

2.5.1 Emanation of Radon

The release of Radon atoms from mineral grains to the pore or joint space can result through grains is too small, α -recoil diffusion or through a recoil effect, which the emerging Radon atom receives at the α -decay of its precursor ²²⁶Ra. Because the Radon diffusion coefficient in mineral is the dominating process[19].

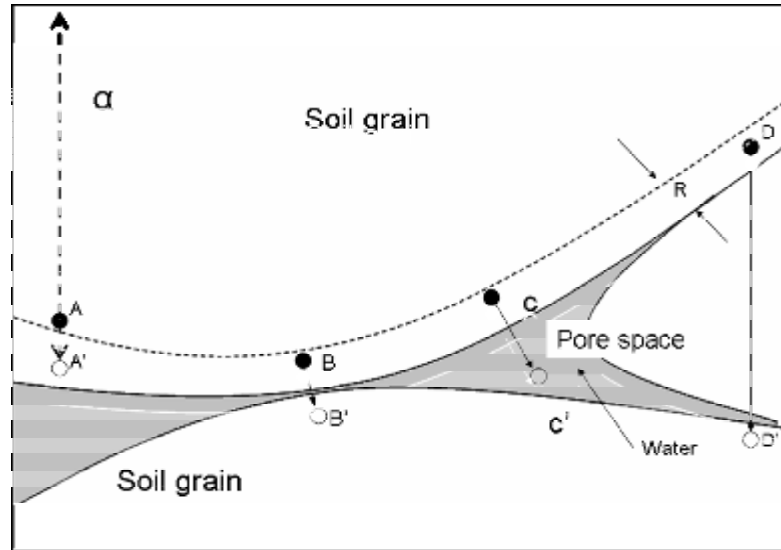


Figure 2.2: Schematic Illustration of Radon (^{222}Rn) Recoil Trajectories in and Between Soil Grains.

The recoil distance lies in the range of $0.02\text{-}0.07\mu\text{m}$ within mineral grains, so a fraction of generated Radon atoms is catapulted into the pore space (Figure 2.2). The fraction of Radon atoms which enters the pore space is called emanation coefficient or emanation power [19].

Figure 2.2: Two spherical grains are in contact at point B. The stippled portion of pore is water-filled. The recoil range, R of the Radon atoms is indicated by the dashed line. ^{226}Ra atoms, indicated by solid circles, decay, producing an alpha particles and a Radon atom, which may end its recoil at the point indicated by the open circle. At point A the radium atom is too deeply embedded within the grain for the Radon atom to escape. At point B and point D the recoiling Radon atom possesses sufficient energy after escaping the host grain to penetrate an adjacent grain. At point C the Radon atom terminates its recoil in the pore water [19].

In a first approximation, the most important influence on the emanation are ^{226}Ra concentrations of rocks and soils. Of course, Radon concentrations of soil-gas are likely to rise at high ^{226}Ra concentrations of the soil. Indeed, mostly slight differences of ^{226}Ra concentrations in the soil in comparison with greatly varying Radon concentrations show, that subsequent parameters must influence the emanation strongly. One of those parameters is the spatial distribution of ^{226}Ra within the solid phase of the soil. In general, soils have higher emanation rates than the rocks from which they have developed, and a fine-grained soil with its large overall grain surface usually has a larger emanation rate than a coarse-grained one [27].

Another important parameter influencing the Radon emanation is the amount of soil moisture. Many scientists research have been recommend to investigations positive correlation between emanation coefficient and soil moisture content [19]. The emanation rate can differ up to a factor of 30 between a dry and a water saturated soil [19]. This is due to the different travel distances of a recoiled Radon atom in water and gas. Within soil water Radon is catapulted over a distance of 0.1 mm and within the soil-gas it travels 63 mm [19]. Because many soil pores have diameters smaller than 63 mm, a fraction of Radon is catapulted through a dry pore space and embedded within the adjacent mineral grain (Figure 2.2). Consequently, an increase of soil moisture will adsorb the recoil energy partly, and the probability for an atom remaining within the pore space is enhanced [27].

If the ^{226}Ra concentration, porosity and emanation for a type of soil are known, the maximum Radon concentration that can occur in the pore air can be calculated from eq. (2.1).

Equation (2.1) is used to calculate the maximum Radon concentration in the soil's pores when they are completely filled with either air or water[20].

$$C_{\max} = Aed(1 - p) / p \quad (2.1)$$

where

C_{\max} is the maximum Radon activity concentration (Bq m^{-3}) in pore volume with absolutely no ventilation (0 ach);

A is specific activity (Bq kg^{-3}),

e is emanation (Fraction of all Radon atoms formed that emanate the pore space);

d is compact density (kg m^{-3}), (normal for mineral soils: 2700kg m^{-3}),

p is porosity, ratio of pore volume to total volume; ach stands for air changes per hour.

The volume of C_{\max} increases as the values of p falls[20].

2.5.2 Migration of Radon

The term Radon migration describes the movement of Radon atoms within the litho-, pedo-, hydro- or atmosphere. Usually, this term is used for the transport within the soil. There are two transport mechanisms to move Radon from its place of origin: diffusion and convection.

Transport of Radon through the soil takes place by diffusion and/or with air ambient gases like CO_2 and CH_4 or water moving in the soil horizons. Moving air can be driven by wind, change in air pressure and percolating

rain or melted snow. Differences of temperature in the soil could be a further cause [20].

A measure for the Radon diffusion is given by the Radon diffusion coefficient (D). This indicates the amount of the atoms, which diffuse through a surface at a given time interval. Beside D an effective diffusion coefficient (D_e) is used too, which describes the diffusion through a surface (or soil volume) regarding the pore space only.[27]

Therefore, D_e is increased in comparison to D by the porosity p :
 $D_e = D / p$ [34].

The Radon diffusion coefficient for soils lies in the range of 10^{-5} and 10^{-10} m^2/s , which are the diffusion coefficient for Radon in the atmosphere and water. Most soils have a coefficient in the order of $10^{-6} - 10^{-7}$ m^2/s [5]. The diffusion distance gives the range of diffusive movement under consideration of the radioactive decay. For wet soils the diffusion distance is only some centimeters, whereby in dry soils it can reach about 1.5m [34].

The diffusion of soil through the ground is related to permeability, which is dependent on grain-size distribution, degree of compaction and the water content of soil. Rodgers and Nielson (1991) have described the parameters governing Radon transport in detail [27]. Table 2.3 lists diffusion coefficients for Radon in some soil types [20].

Table 2.3 : Diffusion Coefficient, D for Radon.

| Medium | D (m^2/s) |
|--------------------------|-----------------------------|
| Air | 10^{-5} |
| Boulders – coarse gravel | $10^{-5} - 5 \cdot 10^{-6}$ |
| Dry sand | 10^{-5} |
| Moist sand | $2.5 \cdot 10^{-7}$ |
| Clayey till | $8 \cdot 10^{-8}$ |
| Water | 10^{-9} |

Table 2.3: Radon diffuses through coarse gravel about as easily as in the air, while there is very little diffusion through a water-saturated clay [27].

2.5.3 Exhalation of Radon

The term Radon exhalation or flux marks the passage of Radon from the soil to the atmosphere. A measure of exhalation is given by the exhalation rate, which is the amount of atoms leaving the soil per surface unity and time interval. Even stronger than the migration, exogenous parameters control the exhalation [27].

It is suitable to distinguish between meteorological conditions influencing soil-physical parameters and conditions, which change the Radon concentration directly. Among the first ones, the frequency and amount of precipitation are important, which influence soil moisture content and gas permeability. The second group includes parameters like atmospheric pressure, temperature, wind force and precipitation again. Rainfall or snow cover can lead to a temporal sealing of the soil surface, whereby Radon is accumulated beneath the sealing, and the exhalation rate is minimized.

If the overall influence of the soil moisture on emanation, migration and exhalation are considered, the exhalation rate is largest under a moderately damp soil. Under these conditions, only small pores are filled with water, resulting in a high emanation rate. The larger pores are still dry, so relatively large migration distances are possible.

A change of atmospheric pressure can influence the exhalation rate, which is usually correlated negatively with the atmospheric pressure gradient. With increasing pressure, atmospheric air with low Radon concentrations is pushed into the soil, whereby the exhalation is decreased. It was noticed during own investigations, that in dependence of the soil permeability, the reaction of the exhalation on changing pressure can be delayed; thus a fine-grained soil showed a phase shift of several hours, starting with a pressure difference of +27 mbar between 0.8 m depth and soil surface [27].

The impact of the temperature gradient adjusting between soil and atmosphere is beyond dispute [19].

Wind force is a pretty unknown exogenous parameter on the exhalation. While Kovach (1945) found an increase in exhalation rate with an increase in wind force and Crozier (1969) observed the opposite behavior [31]. It seems to be important, if the wind creates an excess or a low pressure above the soil surface, which is controlled by large and small scaled topographical situations [27].

While the processes of emanation are largely known and described in the literature at least qualitatively consistently, the processes of migration and especially of exhalation are still discussed controversial. This is explained mainly by different intensities of exogenous influences on the three processes. While the emanation is mainly controlled by soil-physical parameters (like ^{226}Ra concentration, grain size), migration and exhalation are influenced much stronger through exogenous processes (precipitation, temperature, air pressure, wind), which change quickly and distinctive. This leads to fluctuations in the intensity of the influences on migration and especially on exhalation [27].

2.6 Depth Dependence of Radon Concentration in the Soil Air

Radon concentration has depth dependence in soil. The concentration increases with depth, and may reach a maximum at a depth of 2 m in soil. The exhalation upwards of the Radon gas in soil is not only a process of diffusion but also of forced exhalation. One possibility is a carrier gas, like bubbles moving upwards through water-filled cracks. Another is a pumping effect by compression and decompression in the ground, possibly in connection with earthquakes [20].

The soil is considered to be porosity homogeneous, then the Radon concentration $C(z)$ has a relation with the depth (z) of the soil and therefore the diffusive flux density of Radon can be described by the following equation (2.2) [28].

$$J = -D_e \left(\frac{dC}{dz} \right)_{z=0} \quad (2.2)$$

$$D_e = \frac{D}{p} \quad (2.3)$$

Since

J : Diffusive flux density of Radon activity per unit of pore space of the soil. (the activity flux density Bq/(m².s))

D : Diffusion coefficient (m²/s).

D_e : Effective diffusion coefficient (m²/s).

C : The activity concentration of Radon in soil air (Bq/m³).

z : Soil depth (m).

p : porosity.

The Radon diffusion equation is given by [28]

$$\left(\frac{D_e}{P} \right) \frac{d^2C}{dz^2} - lC + b = 0 \quad (2.4)$$

there SI units is used and, l denotes decay constants (1/s),

b : Constant correlates diffusion rate of Radon in the medium (sources) to the pore space in the soil, with units (Bq/(m³.s)).

For simplicity lets take ($\beta=0$) (which means without Radon sources in the medium) the equation (2.4) becomes:

$$\left(\frac{D_e}{P} \right) \frac{d^2C}{dz^2} - lC = 0 \quad (2.5)$$

The solution of the above equation is:

$$C(z) = C_o \exp \left[- \left(\frac{l p}{D_e} \right)^{1/2} z \right] \quad (2.6)$$

Since: $C(z)$: Radon Concentration in depth (z) under Ground surface at any time.[28]

Table 2.4: Approximate Values of Porosity of Some Types of Soil. The Porosity is the Proportion of a Volume Filled with Air.[5]

| Soil types | Sand | Gravel | Morain | Packed Morain | Blasted rock |
|------------|------|--------|--------|---------------|--------------|
| Porosity | 0.40 | 0.40 | 0.30 | 0.25 | 0.40 |

Generally, the depth dependence of the Radon concentration is different in various types of soil. The porosity is an important parameter because it differs from one type of soil to another. Table 2.4 gives approximate values of the porosity of some types of soil. The porosity of clay is missing because of its dependence of the water content of the clay. A second important parameter is the diffusion coefficient. It is given in Table 2.3 for some media. A third important parameter affecting the soil Radon levels is the moisture content of the soil [20].

2.7 Gaza Strip

It is well known that the Radon exists in soil as previously discussed in different sections. Therefore the measurements of Radon concentration in soil plays an important role in an environmental point view. Thus we will concern to study the geology and geography of Gaza strip, so that to know the types of soil.

2.7.1 Geography:

Gaza Strip is a narrow area, surrounded by the 1948 occupied territories in the east and the north, Egypt in the south and the Mediterranean Sea in the west. The geographical coordinates is 31 25 N, 34 20 E. in respect to land boundaries has a border 11km of Egypt, of 51km with the 1948 occupied territories, and of 40km with coastline [19].

The main topographic areas in the Gaza strip are the coastal planes and large sand dunes, which are about 20 to 40 m in height above sea level. Gaza Strip is very crowded place with area, 360 km² as shown the Map in Figure 2.3 [35].

The climate in Gaza Strip is characterized as Mediterranean, with hot, dry summers and short, wet, cool winters, and it has extremely varying average temperatures and rainfall with altitude and distance varying in accord to the climatic regions. The average temperatures in Gaza Strip in the summer are 29 degrees Celsius, in winter it is 12 degrees Celsius [36]. The land use with Gaza Strip is 24% arable land, 39% permanent crops, 0% meadows and pastures, 11% forest and woodland and 26% other 1993 [36].



Figure 2.3: Gaza Strip

1.1.1 Demography:

The population size of Gaza Strip is estimated at 1,132,063, Which is about 36.3% of the total population in Palestine in 2001; the population is mainly distributed in the cities, small villages, and eight refugee camps that contain two thirds of the population, with population growth rate: 3.97% (2000 est.), in addition, there are some 6,500 Israeli settlers (July 2000 est.).[36]

Age structure: 0-14 years: 50% (male 289,954; female 275,628), 15-64 years: 47% (male 271,365; female 263,197) and 65 years and over: 3% (male 13,792; female 18,127) (2000 est.). [36]

Birth rate: 43.14 births/1,000 population (2000 est.) [36].

Death rate: 4.31 deaths/1,000 population (2000 est.) [36].

CHAPTER

(3)

**EXPERIMENTAL TECHNIQUES
AND METHODOLOGY**

3.1 Types of Detectors

All detecting methods are based on the interaction of the radiation with matter. Since ionization is an important process for radioactivity, most detectors exploit the signals generated due to ions and electrons. There are different types of detectors for radiation.

3.1.1 Ionization Chamber

Ionization Chamber consists of a detector chamber, a voltage supplier (battery), an ampere meter, and a load resistor.

Ionizing radiation enters the detector chamber and ionizes the mixture of gas in it. The electrons drift towards the positive electrode and ions move towards the negative electrode. The number of ion pairs is proportional to the number of ionizing particles entering the detector chamber. Thus, the current is proportional to the intensity of ionizing radiation [37,38].

3.1.2 Proportional Counters

In proportional counters, the high voltage applied to the electrodes created a strong electric field, which accelerate electrons. The electrons, after having acquired the energy, ionize other molecules. Production of secondary ion pairs initiates an avalanche of ionization by every primary electron generated by radiation. Such a process is called **gas multiplication**.

The gas multiplication makes the detection much more sensitive. Yet, the current is still proportional to the number of primary ion pairs. When voltages applied to proportional counters get still higher, sparks jump (arcs) between the two electrodes along the tracks of ionizing particles. These detectors are called **spark chambers**, which give internal amplification factors up to 1,000,000 times while still giving an initial signal proportional to the number of primary ion pairs [37,38].

3.1.3 Geiger-Muller Counters

Geiger-Muller counters are the most widely used radioactivity detectors. They are often called Geiger counters, which are essentially a spark counter operating at still higher voltage. The voltages depend on the mixture of gases in the detector chamber. At a high voltage, a single primary ion pair causes a spark to jump between the electrodes.

Every spark gives a pulse registered either across the two electrodes of the chamber or across the resistor. Electronic means count the number of pulses. The counter can also be made to give an audible signal for each pulse. The intensity of the pulse is related to the number of primary ion

pairs, but we are often more interested in the number of ionizing particles entering the chamber [37,38].

3.1.4 Scintillation Counters and Fluorescence Screens

Scintillation counters: scintillation counters are commonly used for X-rays and gamma rays. The output pulses from a scintillation counter are proportional to the energy of the radiation. Electronic devices have been built not only to detect the pulses, but also to measure the pulse heights. The measurements enable us to plot the intensity (number of pulses) versus energy (pulse height), yielding a spectrum of the source [37].

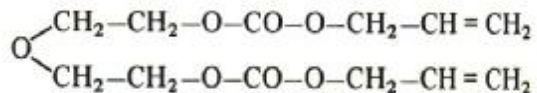
Fluorescence Screens: Fluorescence material absorbs invisible light and the energy excites the electron. De-exciting of these electrons results in the emission of visible light. By mixing different materials together, we have engineered many different fluorescence materials to emit lights of any desirable colors [37,38].

3.1.5 Solid State Nuclear Track Detectors (SSNTDs)

Solid state detectors are used for accurate measurements of radiation energy. Although solid state detectors are based on ionization, they are very different from ionization chambers, proportional counters, and Geiger counters. Solid State Nuclear Track Detectors (SSNTD) have been used for a long time for Radon measurements. SSNTD are sensitive to the alpha particles in the energy range of the particles emitted by radon. However SSNTDs are largely insensitive to beta and gamma rays. In the other words, beta and gamma rays do not produce etchable individual tracks. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light. They of course do not require an energy source to be operated since their detecting property is an intrinsic quality of the material they are made of [20].

Three types of commercially available SSNTDs are:

- 1) Polyallyl diglycol carbonate ($C_{12}H_{18}O_7$) known as CR-39, with appearance is clear, colorless, rigid plastic, density: $1.30g.cm^{-3}$ and chemical structure:



- 2) Cellulose nitrate ($C_6H_8O_8N_2$) known as CR-85.
- 3) Plastic track detector known as CR-115.

CR-39 is a better detector as compared to other detectors used for Radon concentration measurement [39].

This is due to the fact of the advantages of the detector of CR-39 of measuring the Radon concentration which is cheap and can be easily obtained. Therefore, this type of detectors have been used throughout our work so that a reasonable result can be obtained.

CR-39 is a clear, stable plastic which is sensitive to the tracks of energetic protons, alpha-particles and heavier nuclei. After exposure, the tracks may be revealed by etching the material in solutions such as caustic alkalis.

3.1.5.1 Track Formation

When a charged nuclear particle enters the plastic it creates a trail of radiation damage along its path, known as a latent track, shown schematically in Figure: 3.1.

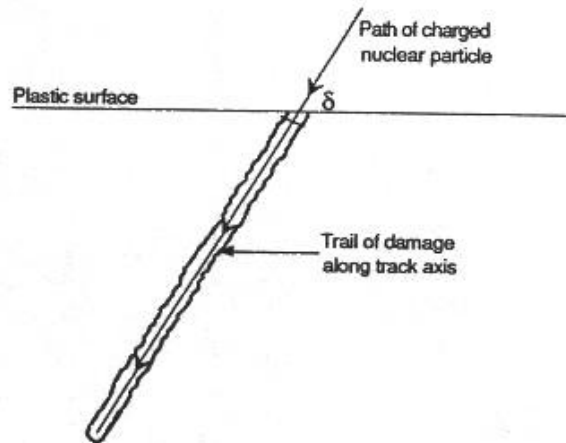


Figure 3.1: Creating an Alpha Particle Track.

This may be revealed by etching the plastic in a suitable reagent such as NaOH. Immersion in NaOH results in bulk etching of the material at a characteristic rate known as the bulk etching rate (V_B).

3.1.5.2 Geometrical Construction of Etch Cones [20,38,39,40]:

It is easy to understand the existence of mechanical track by using the chemical etching when studying the vertical falling of the particles on the detector surface. For simplicity, consider that the bulk etching velocity (V_B) and track etching velocity (V_T) are constant. At etching time (t), the track reaches a distance L from the original surface of the detector.

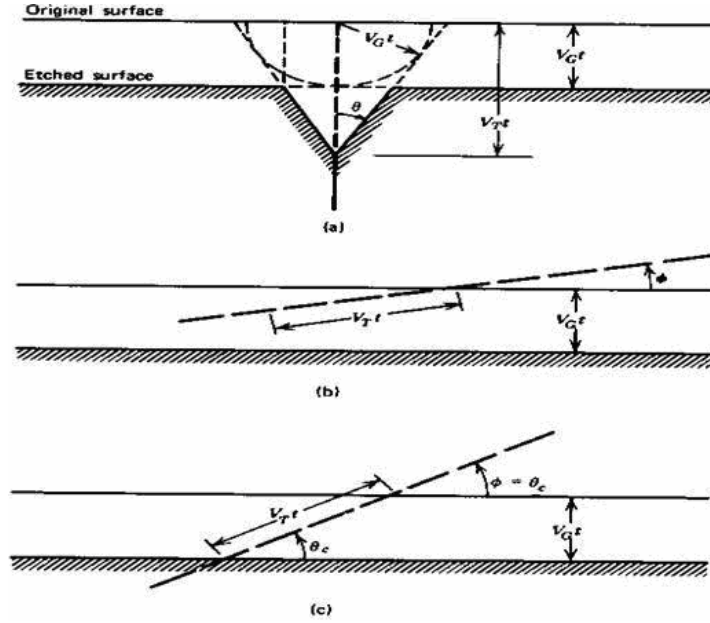


Figure 3.2: Etching an Alpha Particle Track

Figure 3.2 illustrate the etching of an alpha particle track that incident on the surface of CR-39. so L given by:

$$L = V_T . t \quad (3.1)$$

when the surface was etched by a velocity V_B then the length of the track is:

$$L_e = (V_T - V_B) . t \quad (3.2)$$

for each point of track, the etching solution has a velocity equal to the bulk etching velocity (V_B). At an instant of $t(y) = y/V_T$, the etching solution reaches to the point y then the latent etching displacing away from y by a distance equal to $V_B(t - t(y))$. As the depth of track increases, the difference between from t and $t(y)$ will decrease consequently and yields to create a conical shape of angle q_c given from the triangle TAD as illustrated in Figure 3.3, then

$$\sin q_c = \frac{V_B . t}{L} = \frac{V_B . t}{V_T . t} = \frac{V_B}{V_T} \quad (3.3)$$

where q_c : critical angle of etching

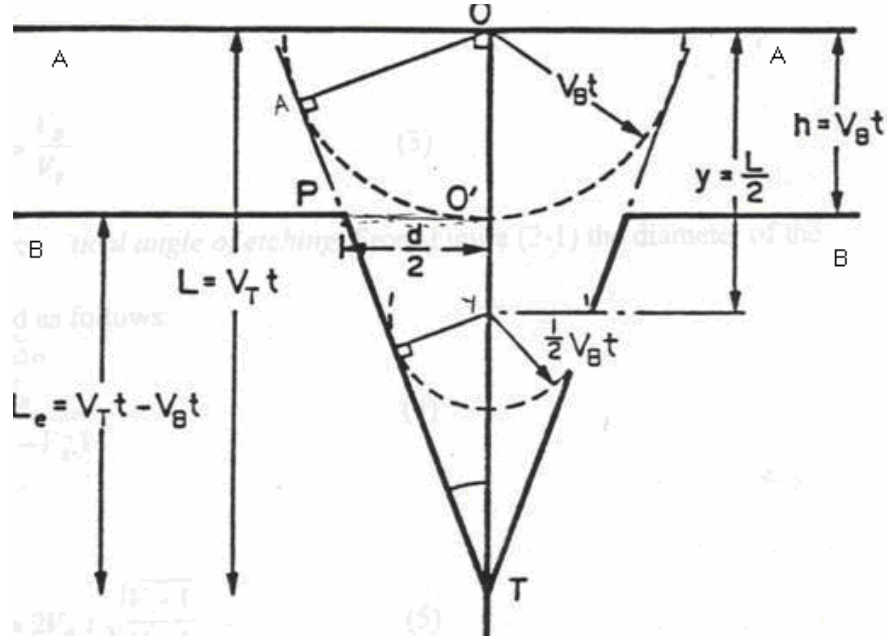


Figure 3.3: Geometrical Construction of an Etch Cone

The etch-pit diameters can be calculate from Figure 3.3, as follows:
 From Figure 3.3: Draw a line AA representing the initial, pre-etch plastic surface. Draw a line BB parallel to AA and a distance h representing the bulk surface removed during etching. For an etching time t and bulk etching velocity rate V_B , then $h = V_B \cdot t$. Draw a line OT representing the trajectory of the traversing nuclear particle. Therefore,

$$\tan q_c = \frac{d/2}{L_e} = \frac{V_B}{\sqrt{(V_T^2 - V_B^2)}} \quad (3.4)$$

$$d = 2 \cdot V_B \cdot t \cdot \sqrt{\frac{V_T - V_B}{V_T + V_B}} = 2 \cdot V_B \cdot t \cdot \sqrt{\frac{V - 1}{V + 1}} \quad (3.5)$$

where: $V = \frac{V_T}{V_B}$: track etching rate, this is an important parameter that useful in determining the registration properties of charged particles in dielectric media. This ratio also gives us parameters such as 'etching efficiency' and 'critical angle' (q_c).

For high-Z (i.e. heavily-charged) particles, such as fission fragments, V_T can be many times V_B (the general velocity of etching in the medium) ($V_T \gg V_B$), $V \gg 1$, consequently:
The diameter d (fission fragments) after an etching time t being, and the length $L = V_T \cdot t$. This is especially case in crystalline media, and;

$$d = 2.V_B.t \quad (3.6)$$

Form this equation (3.6) we can measure the bulk etching velocity alpha particles (V_B) from measuring the etch-pit diameters for fission fragments and etching time known.

For alpha particles, however, $V = \frac{V_T}{V_B}$ is not very high – e.g. In the CR-39 plastic, the value of V may only be 2 to 3. To measure V_B in a plastic is, of course, very easy.[20,39]

Let x is the ratio of the etch-pit diameters for normally-incident as to those for normally-incident fission fragments at any given etching time (t), we notes:

$$x = \sqrt{\frac{V-1}{V+1}} \Rightarrow V = \sqrt{\frac{1+x^2}{1-x^2}} \quad (3.7)$$

$$V_T = V_B \cdot \frac{1+x^2}{1-x^2} \quad (3.8)$$

From this equation we can measure the track etching velocity alpha particles (V_T) from etch-pit diameters known.

We can calculate the etching rate for a detector when exposed to two sources alpha particles and fission fragment through the measure of etch-pit diameter for fission fragments using equation (3.6) and the track etching velocity of the alpha particles by measuring the etch-pit diameters for alpha particles using equation (3.8) [20,38,39,40].

3.1.5.3 Characteristics of Alpha Particle Tracks in Polymers

The growth of etch pits along the alpha-particle tracks in CR-39 detectors is shown in Figure 3.4. The etched track grows initially with a cone-like structure. The track walls are curved because the track etching rate increases with decreasing particle range. When the etching reaches the end of the particle range the track is said to be "etched out". All further enlargement of the track now proceeds as a result of bulk etching - the track is said to be "over-etched". Continued over-etching enlarges the track but gradually the cone-like structure is destroyed [39].

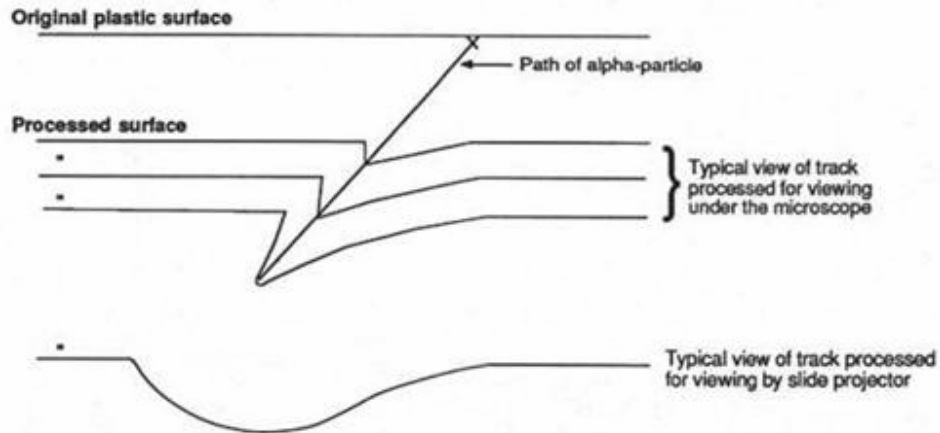


Figure 3.4: Growth of An etched Alpha Particle Track.

The fact that the plastic detects alpha-decays from a finite height above the plastic surface, that is, a finite depth in the sample, enables the track count in units of tracks per square centimeter per unit time to be converted to activity per unit mass of material [39].



Figure 3.5: Tracks Formation on CR-39 Detectors After Chemical Etching

3.1.5.4 Tracks Chemical Etching

Chemical etching (CE) is usually carried out in a thermostatically-controlled bath at temperatures ranging from 40⁰C to 70⁰C (exceptionally, up to ~90⁰), and the commonest etchant is an aqueous solution of NaOH (or KOH) at a molarity of from 2 to 6 M (e.g. for 6 M NaOH, 6 x 40 (the gram molecular weight of NaOH) = 240g of NaOH is mad into a liter of aqueous solution, using distilled water). Typical etching time, and/or the etching temperature, increase, so dose the size of the resulting etch pit.

The detectors are immersed in the etching solution, which are placed in a constant-temperature water bath. At the end of etching, the detectors are removed, washed in running water, and preferably placed in a small ultrasonic bath of distilled water for a few minutes to remove the etching residue from the etch pits. After drying, the detectors are ready to be counted under an optical microscope. The etched track diameters are typically a few μm in size, although they may grow to 50 μm or more after prolonged etching [20].

3.1.5.5 Tracks Counting Methods and Statistics

The main requirement generally is simply to count etched tracks on a detector. Etch pit "track" sizes and shapes will of course vary: vertically incident alpha particles will form circular etch pits. While the majority of etch pits will be elliptical resulting from alpha particles incident on the detector surface of shallower dip angles. Then consistently ignore any smaller etch pits and any scratches are easily discounted. The genuine track etch pit may be identified by slowly moving the fine focus of microscope up and down and looking for a bright point of internally reflected light at bottom tip of the etch-pit cone as shown in Figure 3.6 [20].

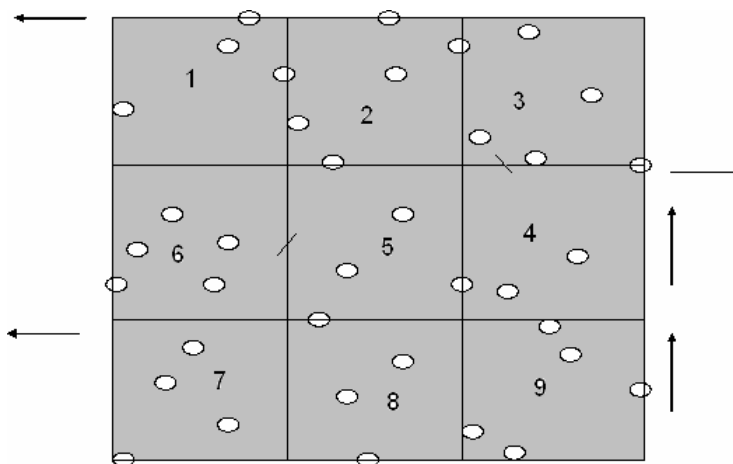


Figure 3.6

Figure 3.6: Systematic scanning by an optical microscope fitted with a movable stage. The stage is first moved from right to left along the x-axis for counting tracks in the consecutive filed of view (fov's) designated as 1,2,3,... After having counted all the tracks in the first fov, the stage is moved in such a way that some fiducial mark on. Say, the extreme right-hand boundary now falls on the extreme left-hand boundary, and so on. At the end of the first line, the stage is moved upwards along the y-axis, again using some fiducial mark to ensure exact converge of all consecutive fov's; the stage is now moved from left to right to count fields 4,5,6, ...; etc. To ensure that no tracks are missed or counted twice, a convention is adopted, e.g. to count a track if it touches or falls on the left vertical and the bottom horizontal boundary of fov, but to ignore those on the other two boundaries.

In any case, it is necessary to count background tracks on sufficiently large areas of detectors to give good statistics. Background track densities of (20-40) tracks/cm² are common.

For example: if genuine track densities are say, 1000 track/cm², then the background tracks would contribute (assuming that one has counted a total of 1000 tracks as well as 40 background tracks) a negligible error. [(1000 ± √1000) - (40 ± √40) = 960 ± √1040, i.e. a total error of 3.36% us an error of 3.16% in the total tracks and ~ 16% in the background tracks]

Poisson statistics are assumed to apply to track counting in common with other nuclear events. In these statistics, the error is given by the square root of the events actually counted. For example, if one counts just 400 tracks, the standard deviation error is 5% (i.e. 400 ± √400), in whatever way one expresses the result. If, for instance, the number of counted tracks (N = 400) was in a field of view which was A = 10⁻³ cm² in area, the track density *r* (tracks cm²) is given by

$$r = \frac{N \pm \sqrt{N}}{A} = \frac{400 \pm \sqrt{400}}{10^{-3}} = (4 \cdot 10^5) \pm 5\% \quad (\text{tracks cm}^{-2}) \quad (3.9)$$

i.e. 4 · 10⁵ ± 2 · 10⁴ tracks cm⁻².

It is absolutely wrong to express the value as

$$\left(\frac{400}{10^{-3}} = 4 \cdot 10^5 \right) \pm \sqrt{4 \cdot 10^5} \quad (\text{tracks cm}^{-2}) \quad 3.10)$$

A few hundred tracks, counted cumulatively over a number of fov's, are usually considered to give reasonable statistic [20].

3.2 Measurement Technique:

We prepared about 160 plastic detectors CR-39 with dimension 2x1.5 cm and dosimeter. The dosimeter is composed of a plastic cup with a circular hole of diameter 7cm in center in the center of lid and depth 4.5 cm as shown in the Figure 3.7. The hole is covered by a piece of sponge sealed into the interior surface of the lid. The detector CR-39 is fixed to the bottom of the dosimeter.

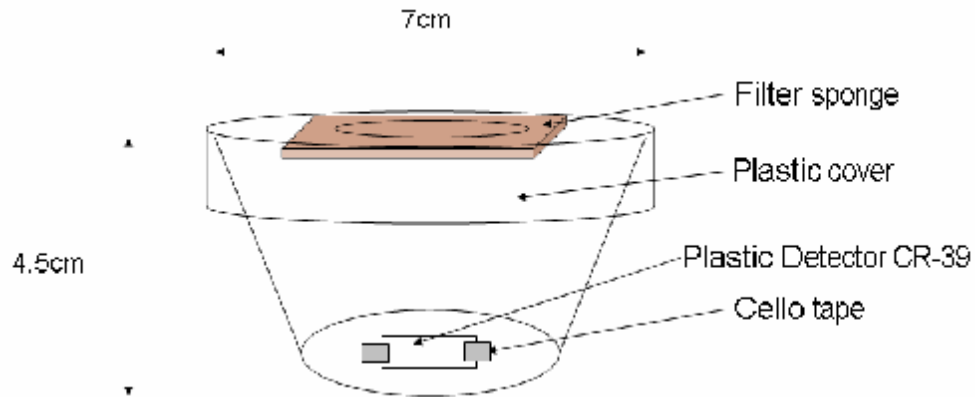


Figure 3.7: Passive Diffusion Radon Dosimeter

The detectors collected from the locations, chemically etching and determined the track density of Radon concentration in Bq/m^3 , as will be discussed later.

3.2.1 Calibration Etching Parameters

The etchants most often used for organic polymers are aqueous solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH). The reactivity of alkaline etchants can be increased by adding alcohol to the aqueous solutions. In practice, the parameters most important for control of the etching speed of the detector are the concentration of the etchants, etching time and temperature [20].

3.2.1.1 Suitable Molarity (Concentration of the Etchants) of NaOH

To find out the suitable molarity of sodium hydroxide NaOH (concentration of the etchant), fifteen (15) dosimeters were exposed to ^{226}Ra (Radon source) of activity 800 Bq/m^3 for ten days. Then the collective detectors were chemically etched using different values of molarity of NaOH at constant temperature 70°C and constant etching time (6 hours). The number of tracks per units area of 1cm^2 were counting using an optical microscope with power of (40x10).

Figure 3.8 shows that the variation of the track density (number of track/cm²) against a molarity of NaOH.

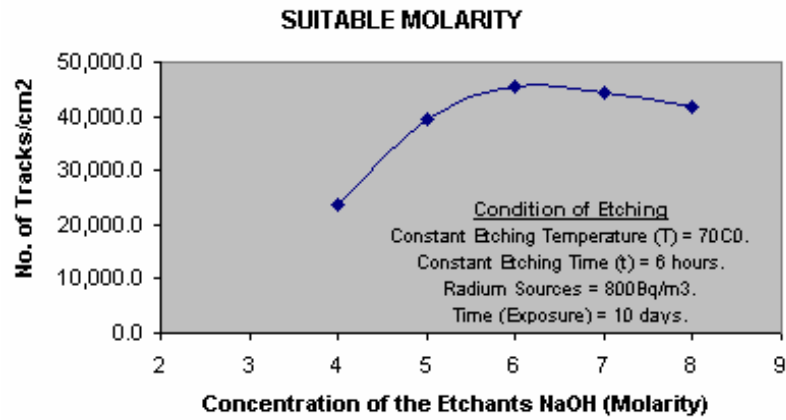


Figure 3.8: Relationship Between Track Density and Molarity

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

3.2.1.2 Suitable Etching Temperature

To find out the suitable etching temperature, we are also repeated the calibration for another detectors. Then the collective detectors were chemically etched using different vales of etching temperature at constant etching time (6h) and constant molarity (6M). The number of tracks per units area of 1cm² were also counting using an optical microscope with power of (4x10).

Figure 4.9 shows that the variation of the track density (number of track/cm²) against a Temperature.

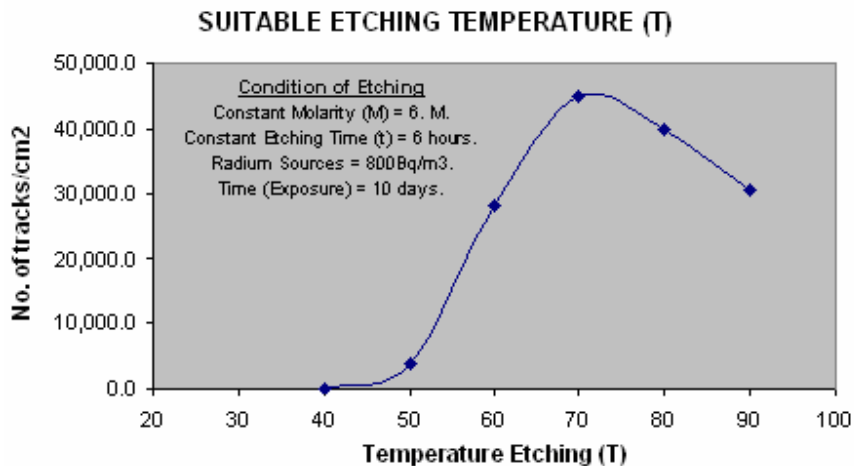


Figure 3.9: Relationship Between Track Density and Etching Temperature (T)

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

3.2.2 Distribution Technique

For Radon measurements, passive method, is used. This method requires digging a hole in the soil of about 11cm in diameter and 50cm in depth. Then 70cm long PVC tube is fixed into the hole, leaving 20cm above the soil surface, (with the covered top end of tube sticking out the ground by about 20cm). At the bottom of each tube a Radon dosimeter is placed, as show in the Figure 3.10. The dosimeter is a plastic container, containing a CR-39 detector, as previously described.

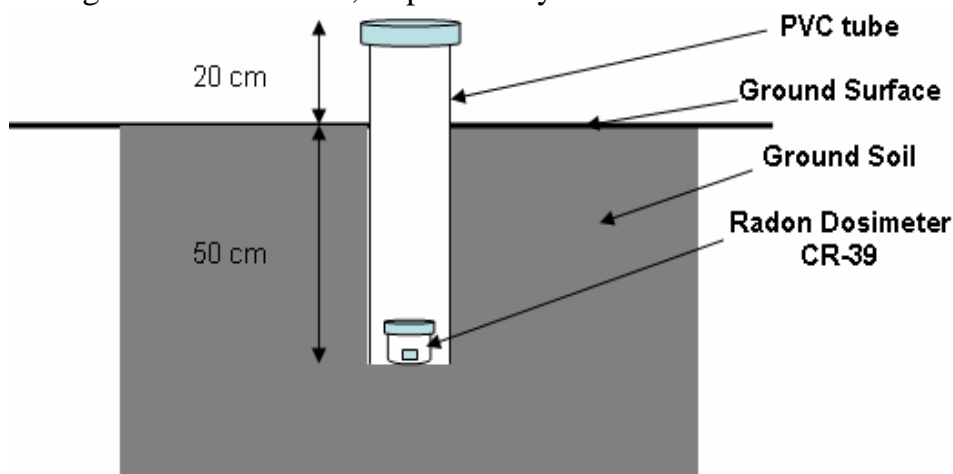


Figure 3.10: Distribution Technique

3.2.2.1 Method for Measuring Radon by SSNTDs:

Solid State Nuclear Tract Detectors (CR-39) is used to measure radon-222 concentration in soil air at the selected area. One hundred sixty (160) CR-39 dosimeters were distributed in five defereent locations on Gaza (East Biet Hanoun, West Biet Hanoun, Al Shaaf, East JAbalia and Biet Lahia).

The exposure time for the dosimeters was 60 days during the months September, October and November of 2004 to allow radon gas to come to an equilibrium level. nly 128 dosimeter were found in place and collected, while the remaining 32 dosimeter (only 20 from Biet Lahia location) were considered lost. The collected detectors were chemically etched using a **6.00 M** solution of **NaOH**, at a temperature of **(70 ± 0.2) °C**, for 6 hours, (standard etching condition).

The CR-39 detectors were mounted vertically in a stainless steel spring and then immersed in the etching solution inside a water bath. At the end

etching process, the detectors were washed thoroughly with distilled water and then left to dry. Each detector was counted visually using an optical microscope with a power of **(40 x 10)**. We are measured the average number of tracks in 1cm^{-2} .

3.2.3 Determination of Radon Concentration:

Radon concentration in surrounding air is measured in terms of Bq/m^3 , since the most regulatory reference levels are specified in this unit. Determination of radon concentration and the standard deviation (S.D.) in soil air at north Gaza are carried out by the following equations [34].

$$C (\text{Bq} / \text{m}^3) = \frac{C_0 (\text{Bq} \cdot \text{d} / \text{m}^3)}{r_0} \left\{ \frac{r}{t} \right\}_{\text{det}} . \quad (3.11)$$

$$s_n (S.D.) = \sqrt{\frac{\sum_k^n (x_k - \bar{x})^2}{n}} \quad (3.12)$$

where,

C_0 : The total exposure of ^{226}Ra (Radon source) in term $\text{Bq}\cdot\text{d}/\text{m}^3$,

r_0 : Track density (number of track / cm^2) of detectors exposed to ^{226}Ra .

r : Track density (number of track / cm^2) of distributed detectors.

t : Exposure time (days) of distributed detectors.

$s_n(S.D.)$: Standard Deviation

Simply, a number of dosimeters were exposed to a known dose of ^{226}Ra , (Radon source) for a period of time. Then those dosimeters were collected and treated chemically etching. The average numbers of tracks/ cm^2 were observed. These detectors were considered as a calibration standard [27,41].

Similar method is also obtained for track detectors techniques to determine the calibration constant (factor). This is derived by dividing the track density by the total exposure of radon source. Then to equation (3.11) for radon exposure becomes as follows [27,41].

$$C (\text{Bq} / \text{m}^3) = \frac{1}{K} \left\{ \frac{r}{t} \right\}_{\text{det}} . \quad (3.13)$$

since,

$$\frac{1}{K} = \frac{C_0(\text{Bq}\cdot\text{d}/\text{m}^3)}{r_0(\text{track}/\text{cm}^2)} \Rightarrow K = \frac{r_0(\text{track}/\text{cm}^2)}{C_0(\text{Bq}\cdot\text{d}/\text{m}^3)}$$

where K is called the calibration factor in terms of ($\text{track.cm}^{-2}/ \text{Bq.d.m}^{-3}$), or a calibration coefficient was determined experimentally.

3.2.4 Calibration Technique:

To determine the calibration factor (K), we have prepared ten 10 dosimeters and exposed for 46 days of ^{226}Ra (radon source) of activity concentration 800 Bq/m^3 . The calibration process for dosimeters used in this survey was carried out at the nuclear laboratory at physics department – Islamic University of Gaza.

It is found that, the reversed calibration constant ($\frac{1}{K}$) was found to be

$$\frac{1}{K} = 0.22 \frac{(\text{Bq}d/\text{m}^3)}{(\text{track}/ \text{cm}^2)}, \text{ and standard deviation error was } \mathbf{12.54 \%}.$$

The overall uncertainty calibration was estimated to be $\pm 10\%$ [42].

Substituting reversed calibration constant in equation (3.13) then, becomes

$$C (\text{Bq} / \text{m}^3) = 0.22 \left\{ \frac{r}{t} \right\}_{\text{det}}. \quad (3.14)$$

This equation was used to determine the Radon concentration at the present work.

CHAPTER

(4)

EXPERIMENTAL RESULTS

4.1 Introduction:

A passive diffusion Radon dosimeter containing CR-39 solid state nuclear track detectors (SSNTDs) were used in this survey. These dosimeters was randomly distributed in soil in different locations at North Gaza Strip (East Biet Hanoun, West Biet Hanoun, Al SHaaf, East Jabalia and Biet Lahia).

Radon concentration at depth in soil described at many factors like (Porosity, Flow velocity, Diffusion coefficient, Moisture,etc.).

The relations of Radon concentration with various types and grades of rock deformation have been studied in the present work with respect to different parameters of the soil cover. The Radon intensity in soil was measured in selected geologically well of depth 50cm.

With several exceptions most of the recent studies of Radon migration in different environments incline to the opinion that the exhalation mechanism of Radon cannot be explained only by its diffusion but also by additional processes such as slow vertical upward flow, which allows Radon to move from larger distances.

4.2 Results of Measurements:

There are considerable differences between the individual Radon concentration values for each location.

4.2.1 Distribution of Measured soil Radon levels in North Gaza.

Table (4.1): Number of Collected Dosimeter (N=128) from Locations and Radon Concentration in Soil Air. C is the Average Concentration and S.D. is The Standard Deviation. (1 pCi/L =37 Bq/m³)

| | Location | No. of Detector | Min. Con. (Bq/m ³) | Max. Con. (Bq/m ³) | C (Bq/m ³) | S.D. (Bq/m ³) | S.D. (%) |
|---|--------------------|-----------------|--------------------------------|--------------------------------|------------------------|---------------------------|--------------|
| 1 | E BH | 40 | 29.35 | 584.15 | 212.70 | 142.05 | 66.78 |
| | • I | 18 | 29.35 | 279.46 | 131.28 | 66.9 | 50.96 |
| | • II | 22 | 105.09 | 584.15 | 279.32 | 152.2 | 54.49 |
| 2 | W BH | 42 | 23.48 | 339.34 | 219.19 | 74.93 | 34.18 |
| | • I | 27 | 83.95 | 318.79 | 207.94 | 61.28 | 29.47 |
| | • II | 10 | 242.27 | 339.34 | 283.86 | 40.20 | 14.16 |
| | • III | 5 | 23.48 | 317.62 | 150.65 | 105.17 | 69.81 |
| 3 | AL SH | 28 | 54.01 | 326 | 150.84 | 88.08 | 53.09 |
| 4 | E JA | 18 | 119.76 | 386.11 | 246.22 | 82.5 | 33.51 |
| | Average (128 det.) | | 23.48 | 584.15 | 207.24 | 34.90 | 16.84 |

Table 4.1: Shows the number of detectors collected from the main groups of locations, the minimum and maximum Radon concentration in soil air of each location measured in Bq/m³, but also the average Radon

concentration (C) and standard deviation (S.D.) for each location in this study.

The Radon concentration and standard deviation for each detector was calculated by equation (3.14) and equation (3.9) respectively. However, the Radon concentration for each location was calculated by summing individual concentration for that locations, and the products also divided by the total number of detectors.

The standard deviation was also calculated by equation (3.12).

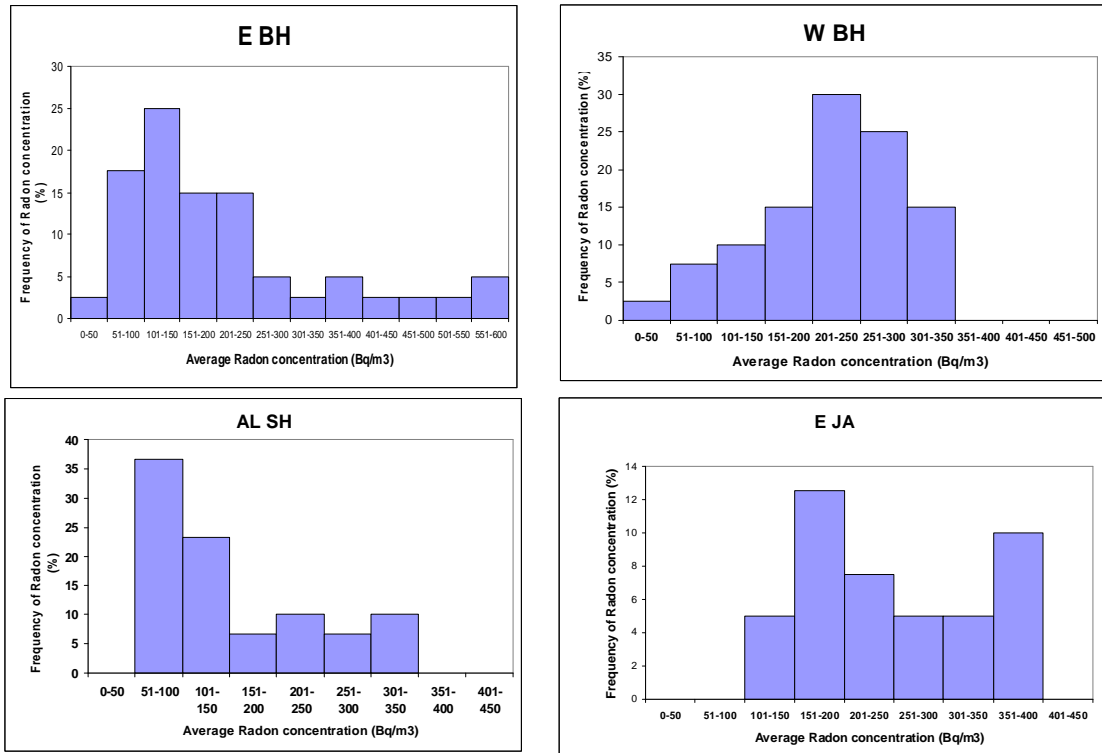


Figure 4.1: Distribution of Measured soil Radon Levels in Four Types of Soil in North Gaza. The Depth of Measurement Its 50 cm.

Figure 4.1: Shows the percentage frequency of distribution measured soil Radon levels in four types of soil in north Gaza.

The results of measurements are evaluated as follows;

- (a) **E BH** 40 measurements, average Radon concentration: $(212.7 \pm 142.1) \text{ Bq/m}^3$, or $(5.8 \pm 3.8) \text{ pCi/L}$.
- (b) **W BH** 42 measurements, average Radon concentration: $(219.2 \pm 74.9) \text{ Bq/m}^3$, or $(5.9 \pm 2.0) \text{ pCi/L}$.
- (c) **AL SH** 28 measurements, average Radon concentration: $(150.8 \pm 80.1) \text{ Bq/m}^3$, or $(4.1 \pm 2.2) \text{ pCi/L}$.

(d) **E JA** 18 measurements, average Radon concentration: $(246.2 \pm 82.5) \text{ Bq/m}^3$, or $(6.7 \pm 2.2) \text{ pCi/L}$.

It is found that Radon concentration ranges from 150 Bq/m^3 up to 250 Bq/m^3 , where the maximum is in **E JA**.

4.2.2 Measured Soil Radon Levels in Four Locations.

Figure 4.2: Shows the percentage frequency of distribution of the average Radon concentration (**C**), **min**, **max**, **S.D.** and **S.D. Error** in soil at four locations of the surveyed area. The concentration in the **East Biet Hanoun (E BH)**, **West Biet Hanoun (W BH)**, **AL Shaaf (AL SH)** and **East JAbalia (E JA)** locations are relatively low. The change of the Radon concentration at the four measuring locations are due to the differences type of soil and moisture contain.

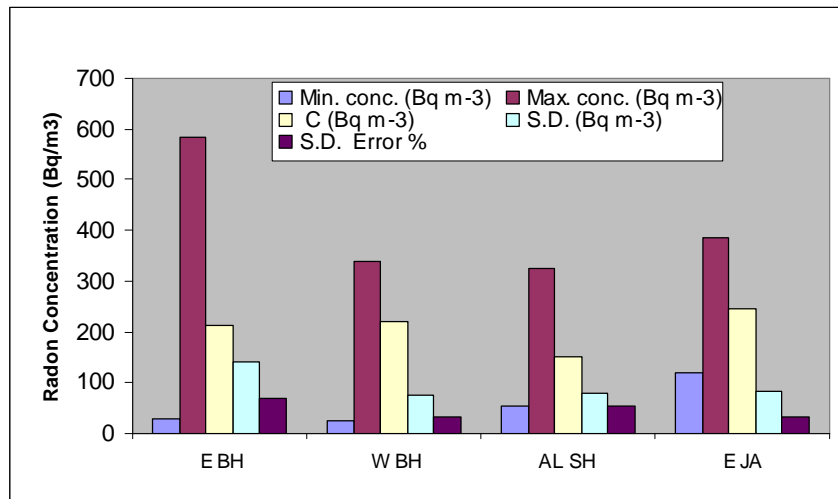


Figure 4.2: Measured Soil Radon Levels in Four Locations. The Depth of Measurement its 50 cm.

From the above figures we can see that in East Biet Hanoun (**E BH**) has both the smallest value of the minimum values 29.32 Bq/m^3 and the largest value of the maximum value 584.15 Bq/m^3 , this is an evidence that the S.D. error is the largest in this study, which implies that the distribution of the Radon gas concentration is relatively different from other locations. This is attributed to the different sand percentages and soil moisture contain from point to point in that locations, where the sand percentage and soil moisture contain differences, plays an important role of Radon emanation throughout soils grains.

The chance of emanation from a rock or soil are greater the more porous the material is, which allows a greater diffusion of the Radon gas [20]. Table 4.2: gives the soil types of the four locations and the results obtained of Radon concentration for each area.

Table 4.2: Distribution of Soil Types in Four Locations at North Gaza.

| | <i>Area</i> | <i>Soil Type %</i> Sand Clay | <i>No. of Detectors</i> | <i>C (Bq/m³)</i> |
|----|---------------------|---------------------------------|-------------------------|-----------------------------|
| 1. | <i>E BH</i> | 80 15 | 40 | 212.7 |
| 2. | <i>W BH</i> | 70 18 | 42 | 219.19 |
| 3. | <i>AL SH</i> | 72 22 | 28 | 115.08 |
| 4. | <i>E JA</i> | 60 30 | 18 | 246.22 |

The soil samples were taken at depth 50cm in the study area. The selected samples were analyzed at Rural and Environmental Center at Islamic University-Gaza to obtained the percentage of component of sand and clay.

4.2.3 Percentage Frequency of Soil Radon Levels in East Biet Hanoun and West Biet Hanoun.

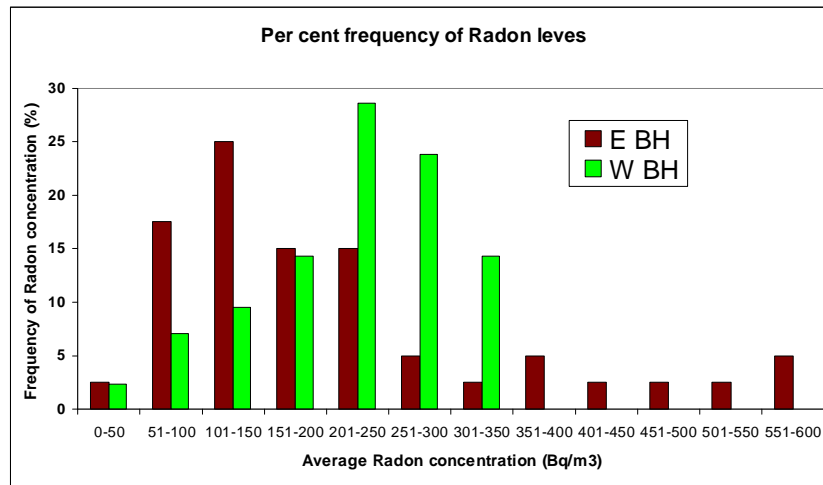


Figure 4.3: Percentage Frequency of Soil Radon Levels in East Biet Hanoun and West Biet Hanoun. The Depth of Measurement Its 50 cm.

Figure 4.3: Shows the average Radon concentrations in soil air at E BH and W BH are relatively equal, with average Radon concentration in soil air at E BH is (212.7 Bq/m³ (5.75 pCi/L), and the Radon concentration in soil air at W BH is 219.19 Bq/m³ (5.92 pCi/L).

From the above figure we can see that there is a percentage of 52% from detectors which range (>200-300) Bq/m³ in W BH location, where as in the location of E BH the percentage is about 42% at range between (>50-150) Bq/m³. This reveals that some detectors at E BH are registered high values of Radon concentrations ranges from (350 up to 600) Bq/m³. however, the W BH less values of Radon concentration up to the 300 Bq/m³ value.

4.2.4 Percentage Frequency of Soil Radon Levels in AL SHAaf and East JAbalia.

There are considerable differences between the individual Radon concentration values for each of the main in the **AL SH** soil and those in the **E JA** soil.

It is found that in **AL SH** soil, the results gives about 150.84 Bqm^{-3} (4.08 pCi/L), whereas for the **E JA** soil gives 246.22 Bqm^{-3} (6.66 pCi/L).

This large differences depends upon the content of soil of that locations.

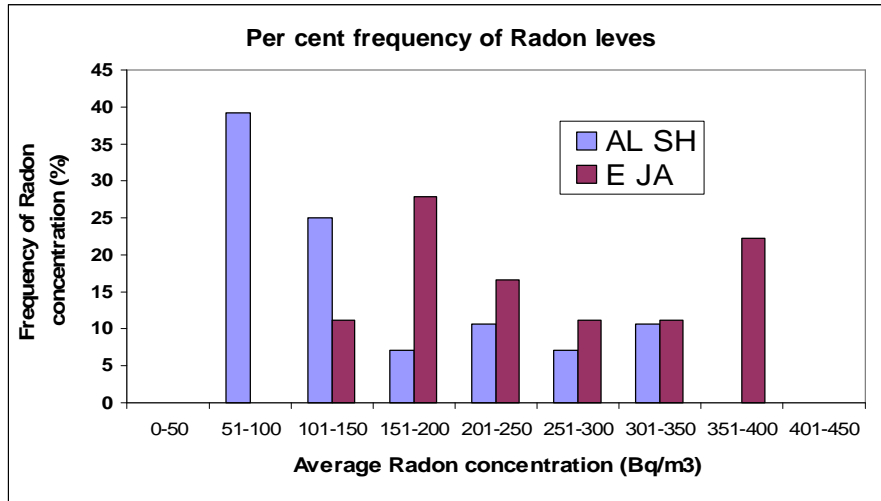


Figure 4.4: Percentage Frequency of Soil Radon Levels in **AL SH**aaaf and **E JA**balia. The Depth of Measurement Its 50 cm.

Figure 4.4: Shows the distribution of Radon levels in soil with differences between the individual Radon concentration values for **AL SH**. The minimum value was 54.01 Bqm^{-3} (1.46 pCi/L) and the maximum about 326 Bqm^{-3} (8.81 pCi/L) for **AL SH**. However for **E JA** the minimum was 119.76 Bqm^{-3} (3.33 pCi/L) and the maximum about 386.11 Bqm^{-3} (10.44 pCi/L). this illustrates that there is a percentage of 64.3% from detectors which range ($>50-150$) Bq/m^3 in **AL SH** location, where as in the location of **E JA** the percentage is about 55.6% at range between ($>100-250$) Bq/m^3 .

The reason for this deviation could be the different percentage of sand and clay existed in both locations in other words percentage.

4.2.5 General Results:

The differences between the individual Radon concentration values for each location are taken into consideration. The overall minimum and maximum values are 23.48 Bqm^{-3} (0.64 pCi/L) and 584.15 Bqm^{-3} (15.79 pCi/L). This indicates that the difference is very large between the two values (Table 4.1).

Figure 4.5: shows the percentage frequency of 128 soil Radon measurements in north Gaza at depth of measurement is 50 cm. the results indicates that 1.6% of the detectors have soil Radon concentration less than 50Bq/m³, 16.4% in range (>50-100) Bq/m³, 18.0% in range (>100-150) Bq/m³, 14.8% in range (>150-200) Bq/m³, 18.8% in range (>200-250) Bq/m³, 12.5% in range (>250-300) Bq/m³, 9.4% in range (>300-350) Bq/m³ and 8.7% above (>350) Bq/m³.

Further, it can be concluded that the highest frequency value (68%) in north Gaza ranges (50-250) Bq/m³ ((1.35-6.76) pCi/L). Results Obtained in soil air at north Gaza was found that the average value of Radon concentration about 207.24 Bq/m³ (5.6 pCi/L). However, the values of Radon concentration range from (23.48 – 584.15) Bq/m³ ((0.64 – 15.79) pCi/L), with value standard deviation error 16.84%, (Table 4.1). This value is smaller than the National average of approximately 10 kBqm⁻³ that range (740-1110) Bq/m³, (27 pCi/L at rang (20-30) pCi/L) [16].

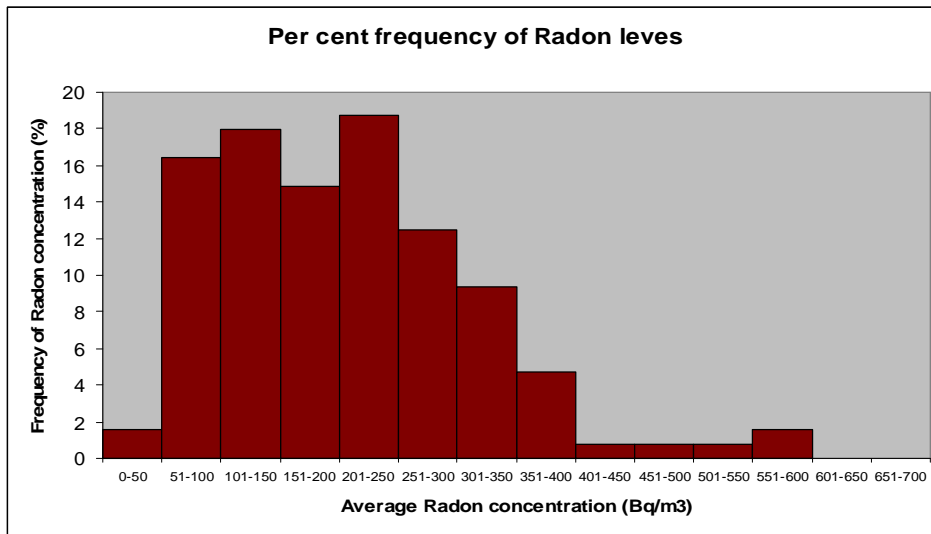


Figure 4.5: Percentage Frequency of 128 Soil Radon Measurements in North Gaza. The Depth of Measurement is 50 cm.

This is probably due to the little content of rocks which contain the main source of Radon (²³⁸U series) in surveyed areas. The nature of those areas which are considered to be rural and farms territories increases the rate of exhalation, as known in farms the soil is prepared for planting by ploughing the soil to depth about 30 cm.

CHAPTER

(5)

DISCUSSION AND CONCLUSION

5.1 Discussion

As discussed previously, that the soil Radon concentration are affected by three factor process. These are emanation, migration and exhalation. The Radon emanation describes the Radon release from the solid phase of the soil (mineral grains, soil particles) to the pore or joint space. The movement of the released Radon atoms through gas or water-filled voids is called Radon migration, which can be a result of diffusive and/or convective processes. Finally, the Radon exhalation describes the passage of Radon from the soil into the atmosphere.

The main parameters controlling the soil Radon concentration on rural areas is: the variety of soil (rocks, sand,...eta), relief and vegetation. These parameters can be modified further by geology of soil at regions.

5.1.1 Variety of soil:

The most important parameter of the soil Radon concentration is the type of bedrock beneath the soil. It is found that, the variety of rocks that contain radionuclide concentrations plays an important factors in Radon concentration. In most cases, rocks with high ^{226}Ra concentrations develop soils with high Radon concentrations. Not only the ^{238}U or ^{226}Ra concentration of a soil controlled by the type of bedrock, but also the gas permeability of a soil, that which determines the migration distance are depends on the bedrock.

In the present study, we have found that most of the soil in all regions are nearly similar in content. However, a remarkable increase in Radon concentration is found in **East JAbalia** rather in **EL SHaaf**. This difference in concentration is due to the type of soil content, where **East JAbalia** has more relatively clay in **EL SHaaf**.

5.1.2 Relief

Investigations in hilly areas have shown that the distribution of Radon concentrations in soil gas depends on the relief and the season [27,34]. Under natural conditions, the geological situation determines the soil development and the soil Radon potential in first approximation. Within one geological unit (same petrography) the potential is modified further by relief, which can be expressed as soil type variety because the soils developed with a strong dependence on the topographical situation under similar climatic conditions.

In the present work, we have also noticed the Radon concentration in East Beat Hanoun, a slight increase in the two regions(I and II as show in table 4.1). these regions have different levels in height, where region II has

lower level, that a humidity can be high and affected the Radon concentration.

The Radon concentrations shown in Fig. 5.1 are median values of the measurements conducted throughout the whole period. Parallel to the median soil moisture contents, the Radon concentrations increased down the slope [27].

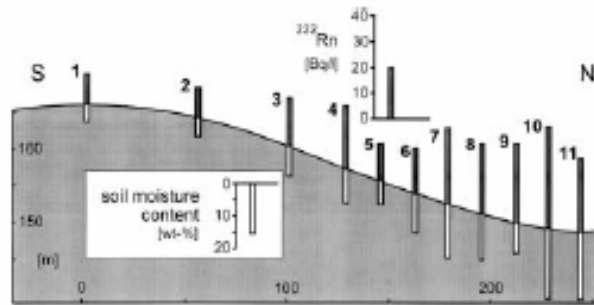


Figure 5.1: Radon Concentrations and Soil Moisture Content (Median Values, Depth of 80 cm) Along the Test Slope [27].

5.1.3 Vegetation cover

The impact of the vegetation on meteorological and physical soil conditions, such as a change in the microclimate or a change in gas permeability and moisture content of soils has its influence on Radon concentration.

In the present work the nature of those four locations are considered to be rural and farms territories increases the exhalation rate, as known in farms the soil is prepared for planting by ploughing. Probably, the destroyed (ploughing) soil structure reduces not only the Radon migration (small exhalation rate), but also reduces its subsequent delivery from depth as well (low concentration within soil gas).

Results Obtained that the mean value of Radon concentration in soil air at north Gaza is smaller than the National average of approximately 10 kBq/m³, is illustrated in Fig. 4.5.

This is probably due to the little content of rocks which contain the main source of Radon (²³⁸U series) in surveyed areas.

The negative correlation between Radon concentration and gas permeability of soils, depending on land use or vegetation cover,

In the present study, several geologically and structurally well investigated localities with different types of soil and were selected; the aim of the study is to measure Radon concentration in soil at north Gaza and to obtain basic information on types of soil in this area.

5.2 Conclusion

It is evident from our measurements that the Radon concentration in soil air varies considerably. Soil types plays major part in varying Radon concentration.

The main factors influencing the Radon intensity through the soil, observed in the present study, can be summarized as follows:

1. The Radon concentration in soil air at north Gaza are typically in values to those normally found in other countries.
2. The higher Radon concentration in soil air at East JAbalia do not create any special environmental and or health problem, because it was smaller than the National average of approximately 10 kBqm^{-3} , hopefully.
3. At present, the action levels for Radon concentration in soil air at north Gaza is under consideration, comparing to others.
4. The main parameters affecting the soil Radon levels are types of the soil (Sand and clay), Radium concentration (U^{238}), moisture contain of soil, and vegetation cover, and relief.
5. The results of the present study in soil at north Gaza, will be used as a data base and source for the development of more specific studies in the regions in environmental point of view.

The present work suggests that more investigation are requested to survey the Radon concentration in other regions in Gaza, and to map the Radon gas in soil at Gaza Strip. This would give a good motivation to remedial the areas of radiation contamination and to protect people of Radon risks.

GLOSSARY

Absorbed Dose, the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram.

Activity, the quantity A expressing the decay rate of a radionuclide, defined as $A = dN/dt = \lambda N$, where λ is the decay constant (s^{-1}) and N is the number of nuclei undergoing spontaneous disintegration. The SI units of activity is becquerel (Bq). 1Bq = 1 disintegration per second. The activity is usually expressed in Bq m^{-3} .

Aerosol, colloidal particles dispersed in the air, that can serve as nuclei to which the solid Radon daughter products can attach themselves.

Alpha Particle, a strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Background Radiation, ionizing radiation arising from radioactive material other than the one directly 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 other parts of the building, in the building material itself, etc.

Becquerel, the international (SI) the unit for radioactivity in which the number of disintegrations is equal to one disintegration per second. A charged particle emitted from the nucleus of an atom during radioactive decay.

Beta Particle, charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Chemical etching of tracks, developing a latent by an etching solution that selectively removes the material of the latent track, thus enlarging it to a point usually observable under an optical microscope.

Concentration of Radon, i.e. its activity concentration; often referred to as radon level; its SI unit is Bq m^{-3} (the volume refers to that surrounding air). Also expressed in Bq (or Ci) per liter of a liquid. $1\text{pCi l}^{-1} = 37 \text{ Bq m}^{-3}$.

Cosmic Radiation, penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem annually.

Coulomb, the meter-kilogram-second unit of electric charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

CR-39, trade name of a track detector made of polyally diglycol carbonate.

Curie (Ci), the quantity of any radioactive material in which the number of disintegrations is 3.7×10^{10} per second. Abbreviated Ci.

Daughter Products, isotopes that are formed by the radioactive decay of some other isotope. In the case of radium (^{226}Ra), for example, there are ten successive daughter products, ending in the stable isotope lead (^{206}Pb).

Decay, Radioactive, disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

Dose or Radiation Dose, a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose Equivalent (H_T), the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the sievert (Sv). The ICRP defines this as the equivalent dose, which is sometimes used in other countries.

Dose Rate, the radiation dose delivered per unit of time. Measured, for example, in rem per hour.

Dosimetry, the theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

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

Emanation, the movement of radon atom from a mineral grain to the pore void, usually as a recoil in the alpha-decay of the parent radium atom.

Etch pit, the pit, of a charged-particle track as result of etching the detector with an appropriate chemical reagent.

Exhalation, emission of Radon from a surface, for example the ground surface or a wall surface, by diffusive or convective movement through pore space.

Exposure, (1) Being exposed to ionizing radiation or radioactive material. (2) a measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the Roentgen.

Gamma Ray, very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

Gray, The international (SI) unit of absorbed dose in which the energy deposited is equal to one Joule per kilogram (1 J/kg).

Half-Life, Radioactive, time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Ionization, the process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionizing Radiation, any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples, alpha, beta, gamma, x-rays, neutrons and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Isotopes, nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

Joule, the meter-kilogram-second unit of work or energy, equal to the work done by a force of one Newton when its point of application moves through a distance of one meter in the direction of the force.

Mole (M), molecular weight of a compound in grams, based on the atomic mass number A of its constituents. A mole contains the Avogadro's number N_A of molecules. $N_A = 6.0220 \times 10^{23}$ molecules.

Natural exposure, an exposure delivered by natural sources.

Natural Radiation, ionizing radiation, not from manmade sources, arising from radioactive material other than the one directly under consideration. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of the natural radiation vary with location, weather patterns and time to some degree.

Natural sources, Naturally occurring sources of radiation, including cosmic radiation and terrestrial sources of radiation.

Neutron, an uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen.

Nucleus, the small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and

neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

Nuclide, a species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

Rad, the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 62.4×10^6 MeV per gram.

Radioisotope, a nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radionuclide, a radioactive isotope of an element.

Rem, the special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

Risk, A multiattribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual or potential exposures. It relates to quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences.

Roentgen (R), the quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 gram of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. Amount of energy is equal to 2.58×10^{-4} coulombs/kg air. The Roentgen is a special unit of exposure.

Sievert, The international unit (SI) of dose equivalent (DE, human exposure unit), which is equal to 100 rem. It is obtained by multiplying the number of grays by the quality factor, distribution factor, and any other necessary modifying factors.

Solid state nuclear track detectors (SSNTDs), insulating materials (e.g. polymers) in which heavy charged particles produce damage trails, etchable into track visible under an optical microscope.

Track detectors, see Solid state nuclear track detectors.

Terrestrial Radiation, the portion of the natural radiation (background) that is emitted by naturally occurring radioactive materials in the earth.

X-rays, penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called Roentgen rays after their discoverer, W.C. Roentgen.

Working level (WL), A unit for potential alpha energy concentration (i.e. the sum of the total energy per unit volume of air carried by alpha particles emitted during the complete decay of each atom and its daughter in a unit volume of air) resulting from the presence of Radon daughter or thoron daughter equal to emission of $1.3 \text{ E}+05 \text{ MeV}$ of alpha energy per litre of air. In SI units the WL corresponds to $2.1 \text{ E}-05 \text{ J}$ per cubic metre.

Working level month (WLM), A unit of exposure to radon progeny or thoron progeny.

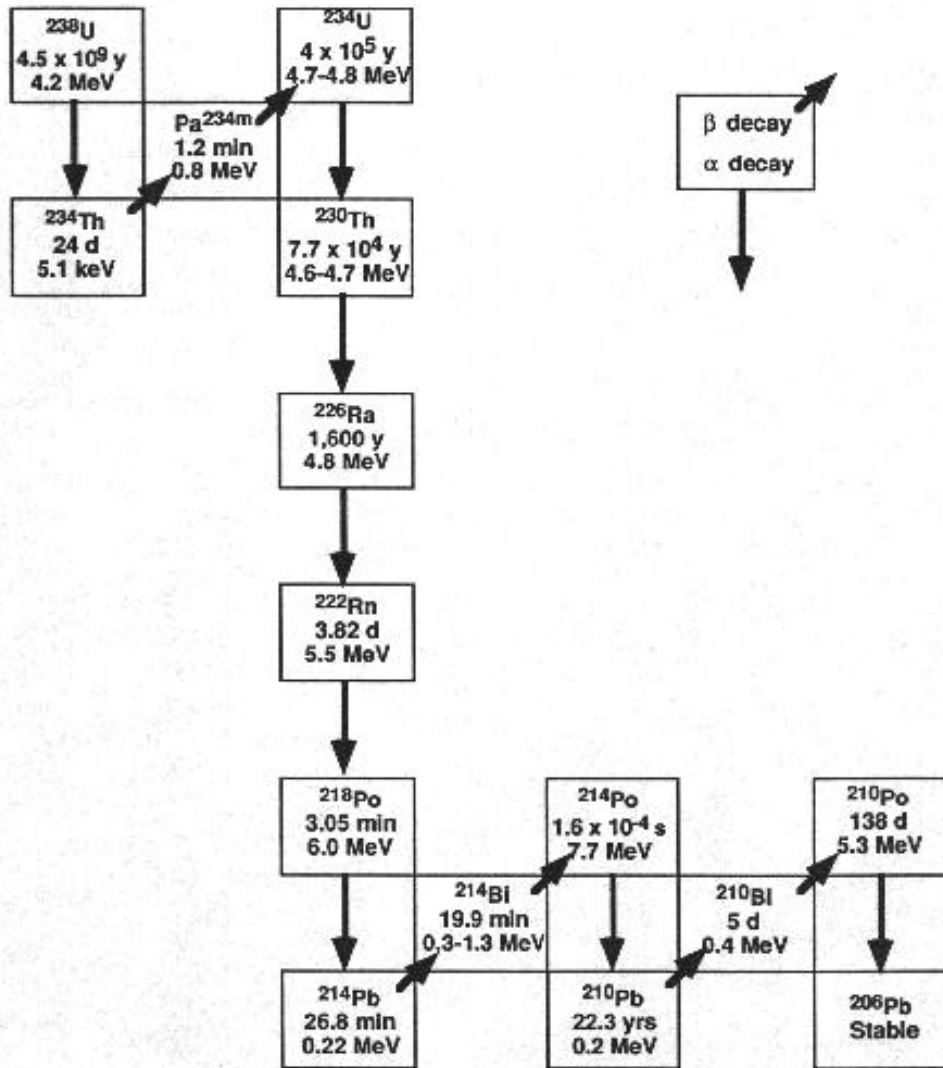
$$1 \text{ WLM} = 170 \text{ WL.h}$$

One working level month is equivalent to 3.54 mJ.h per cubic metre.

APPENDIX (I)

DECAY CHAINS

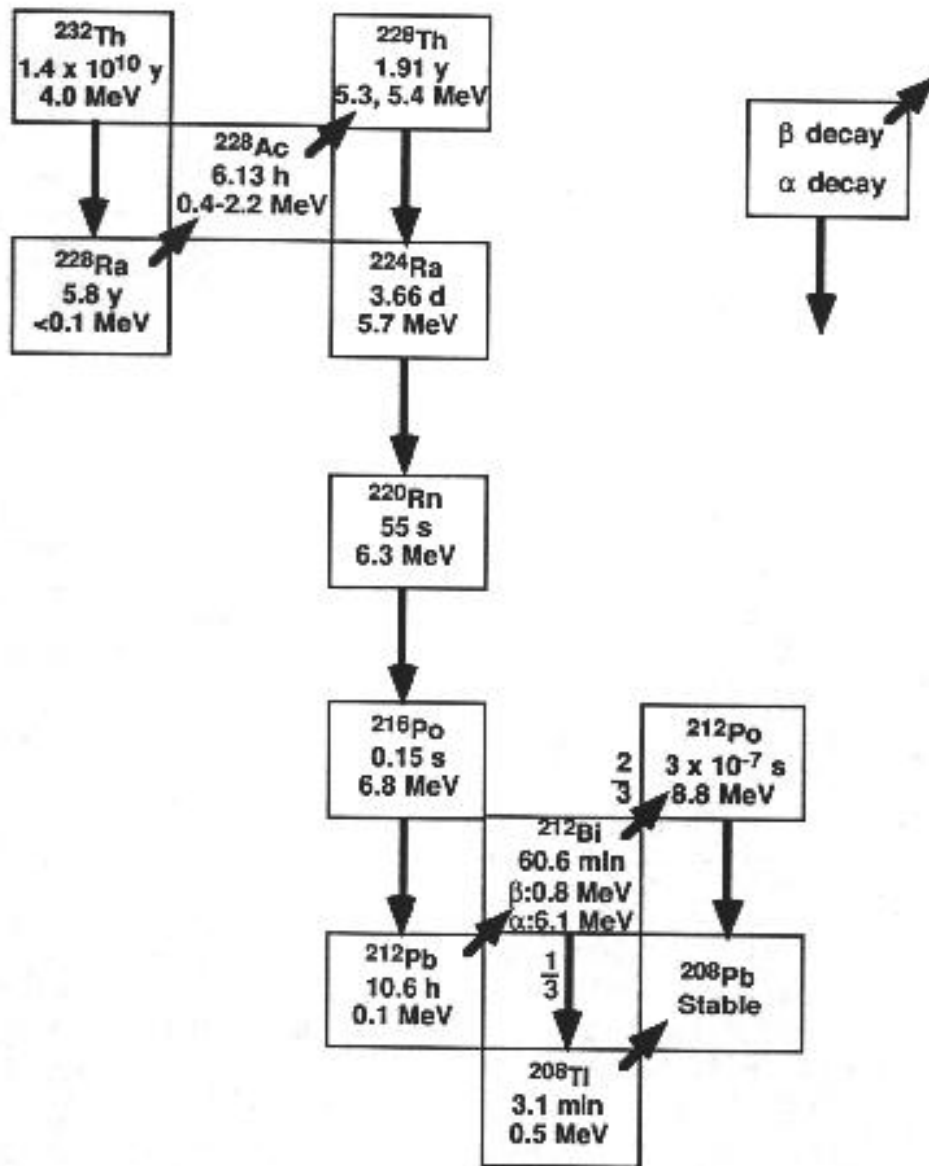
The ^{238}U Uranium Decay Chain. ---> Uranium Decay Chain.



APPENDIX (II)

DECAY CHAINS

The ^{232}Th Thorium Decay Chain. ---> Thorium Decay Chain



APPENDIX (III)

Detectors Distribution in Soil at North Gaza.

**Measurement of Radon Concentration in Soil at North
Gaza, Palestine**

Area Name: EBH....., WBH, BL, E JA, EL SH

Number of Locations in the Area:

Location Name of the Area:.....

Soil Type:

Clay:

Gravel:.....

Coarse Clay:.....

Sand:

Fine Clay:

Silt:

Crushed rock:

Number of detectors:

Exposure period:

Date of Distribution: 10/9/2004

Date of Collective: 10/11/2004

| A/A | Detector Serial No. | Number of track | Soil Radon concentration (Bq.m ³) | Standard Deviation |
|-----|---------------------|-----------------|---|--------------------|
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Comments:.....
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مستخلص

قياس تركيز غاز الرادون في التربة في شمال غزة

تم في هذه الأطروحة قياس تركيز غاز الرادون في التربة في شمال غزة - فلسطين، باستخدام كواشف الأثر النووي في الجسم الصلب (مجراع الرادون السلبي) والمعروفة تجارياً بالاسم (CR-39)، ويعتمد هذا النوع من الكواشف على الأثر الذي تحدثه الجسيمات المؤينة في الأجسام العازلة بما فيها الزجاج والبلاستيك. حيث تحدث هذه الجسيمات آثاراً رقيقة مخفية لا يمكن رؤيتها إلا بالميكروسكوب الإلكتروني حيث يكون قطر الأثر أقل من 10^{-8} سم. ولكن يمكن جعل هذه الآثار مرئية بواسطة الميكروسكوب الضوئي العادي (أي قطر الأثر من مرتبة 10^{-4} سم) بعملية الحك الكيميائي (Chemical Etching).

تم حفر عمق 50 سم بقطر 11 سم في التربة من خلال أنبوب بلاستيكي قطر 4 أنش وطول 70 سم (تم دفن 50 سم في التربة و20 سم بقيت أعلى سطح التربة)، في قاع هذا الأنبوب وضع المجراع السلبي، حيث قفل إقفال محكم من أعلى بحيث لا يدخل الهواء (الرادون) من الغلاف الجوي إلى المجراع.

تم توزيع 160 مجرعا حسب الموقع في المناطق التالية: شرق بيت حانون، غرب بيت حانون، شرق جباليا، بيت لاهيا، والشعف (شرق الشجاعة). تركت الكواشف في الأرض لمدة 60 يوم (شهرين) خلال الأشهر سبتمبر، أكتوبر ونوفمبر من العام 2004، وبعد جمع الكواشف عولجت كيميائياً (الحك الكيميائي) باستخدام محلول هيدروكسيد الصوديوم (NaOH) بتركيز 6.0M وعند درجة حرارة 70° ولمدة 6 ساعات، ثم عدة المسارات المتولدة في الكواشف والموجودة في وحدة المساحة (1cm^2) بعد استخدام المجهر الضوئي العادي بقوة 10×40 .

قد وجد أن تركيز غاز الرادون في منطقة شمال غزة - فلسطين يتراوح بين 23.48Bq/m^3 و 584.15Bq/m^3 ($0.64 - 15.79$) pCi/L، بمتوسط 207.24Bq/m^3 (5.6 pCi/L)، وانحراف معياري مقداره 34.90Bq/m^3 (0.94 pCi/L). حيث وجد أن أعلى متوسط لغاز الرادون في التربة كان في منطقة شرق جباليا وهو 246.22Bq/m^3 (6.66 pCi/L). بانحراف معياري 82.50Bq/m^3 (2.23 pCi/L)، وأقل متوسط لغاز الرادون في التربة كان في منطقة الشعف (شرق الشجاعة) وهو 150.84Bq/m^3 (4.08 pCi/L). بانحراف معياري 88.08Bq/m^3 (2.23 pCi/L).

بكل تأكيد فإن هذه الدراسة قد أجريت لتزويدنا بقياسات تركيز غاز الرادون وآثاره الصحية الناجمة عن ذلك، وخصوصاً من وجهة النظر البيئية.



قياس تركيز غاز الرادون في التربة في شمال غزة

مقدمة من الطالب

نبيل محمد حمد

بكالوريوس في الفيزياء
جامعة أثينا - اليونان

تحت إشراف

أ.د. محمد شبات

د. سمير ياسين

رسالة

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

2005