Sudan University of Science and Technology

College of Graduate Studies

Measurement of Radioactivity Concentration in Soil Samples from Merowe City - Sudan

قياس تركيز النشاط الإشعاعي في عينات تربة من مدينة مروي- السودان

A Thesis submitted for partial fulfilment of the requirement for master

Degree in nuclear physics

By:

Rofida Tahir Ezzeldeen Al-Sadig

Supervisor:

Prof. Nadia Omer Al-Atta

2023

قال تعالى :

تبارك الذي جَعَلَ فِي السَّمَاءِ بُرُوجًا وَجَعَلَ فِيهَا سِرَاجًا وَقَمَرًا مُّنِيرًا(61)

الفرقان آية 61

Dedication:

To those who believed in me…….

Acknowledgment:

This project would not have been possible without the support of many people….

Many thanks to my supervisor, adviser, and mentor Prof. Nadia Omer Al-Atta Who, has been an ideal guide and who read my numerous revisions and helped make some sense of the confusions.

I would like to express my gratitude to my friend ‘Esraa’ who supported me and offered deep insight into the study.

A special thanks to the sisters, whom without this would have not been possible no words can describe how grateful I’m.

And finally, thanks to my, parents, husband and numerous friends who endured this long process with me, always offering support and love.

Abstract

This study aimed to measure the concentration of natural radioactive elements in soil in Merowe City.

Thirty soil samples were collected from different locations. The specific activity was determined by using the gamma ray spectroscopy with high purity Germanium detector (HPGe), The activity ranged from 10.7 to 28.6 $BqKg^{-1}$ for ^{226}Ra, from 12.3 to 53.5 Bq/Kg for ^{232}Th, and 148 to 807 Bq/Kg for ^{40}K. The average absorbed dose of the terrestrial natural existing radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were found to be 48.152 nGy/h. The evaluated annual effective dose is 28.08 µSv/y. The mean absorbed dose is 58.321 nGy/h, and the mean radium equivalent activity is 99.975 Bq/Kg. The external hazard index is 0.757 which is less than one. The representative gamma index was 0.757 also less than one.

The results of this study were compared with other studies and found that the concentrations of ^{226}Ra and ^{232}Th were average with a slight increasing in Potassium ^{40}K .

المستخلص

هدفت هذه الدراسة إلى قياس النشاط الإشعاعي للعناصر المشعة الطبيعية في التربة بمدينة مروي. تم جمع ثلاثين عينة من التربة من مواقع مختلفة، وتم قياس النشاط الإشعاعي للنويدات المشعة الموجودة في التربة باستخدام مطياف أشعة جاما مع كاشف الجرمانيوم عالي النقاء.

تراوح النشاط الإشعاعي بين10.7 إلى 28.6 بيكرل/كجم لـ^{226}Ra، ومن 12.3 إلى 53.5 بيكرل/كجم لـ ^{232}Th ، ومن 148 لـ 807 بيكرل/ كجم لـ^{40}K.

تم قياس متوسط الجرعة الممتصة و وجد انها 48.152 nGy/h و الجرعة الفعالة السنوية 58.321 µSv/y أما مكافئ الراديوم وجد أنه يساوي 99.975 بيكرل/كجم، أيضاً تم قياس مستوى الخطورة الخارجي ووجد أنه يساوي 0.757>1. أيضاً دليل خطورة قاما وجد أنه 0.757>1 .

تمت مقارنة هذه الدراسة مع دراسات أخرى، ووجد أن تراكيز ^{226}Ra و ^{232}Th كانت في المستوى الطبيعي مع زيادة طفيفة في مستويات البوتاسيوم ^{40}K

List of Content:

List of Tables:

List of Figures:

List of Abbreviations:

Abbreviation	Full form
K	Potassium
U	Uranium
Th	Thorium
Ra	Radium
α	Alpha
β	Beta
γ	Gamma
He	Helium
Pa	Protactinium
e	Electron
Bq	Becquerel
Kg	Kilogram
Sv	Sievert
Gy	Gray
h	Hour
HPGe	High Purity Germanium
GPS	geographical positioning system
ev	Electron volt
D	absorbed Dose rate
A_{Ra}	Activity concentrations of radium

A_{Th}	Activity concentrations of thorium
A_K	Activity concentrations of Potassium
Ra_{eq}	Radium Equivalent Activity
H_{ex}	External Hazard Index
I_γ	Representative gamma Index

Chapter One

Introduction

1.1 Introduction:

More than sixty radionuclides can be found in the environment. Natural radioactivity is common in the rocks and soil that constitute planet earth, in water and oceans, and in building materials and homes. There is no place on earth that has no natural radioactivity. Some radioactive nuclides are detectable in soil.

They belong to natural radionuclides such as the members of the uranium and thorium decay series. More specifically, natural environment radioactivity and the associated external exposure due to gamma radiation depend on the geological and geographical conditions and appear at different levels in the soils of each region in the world.
The specific levels of terrestrial radiation are related to the geological composition of each lithological separated area and to the content of the rock from which the soils originated in each area in the radioactive elements of Thorium (^{232}Th), Uranium (^{238}U), and Potassium (^{40}K).

All building materials contain various amounts of radioactivity. For example, materials derived from rock and soil contains natural radionuclides of the uranium and thorium series and the radioactive isotope of potassium. Artificial radionuclides can also be present, such as Cesium (^{137}Cs), resulting from the fallout from weapons testing and the Chernobyl accident. All these can be sources of both internal and external radiation exposures.

1.2 Radioactivity in Soil Surfaces (Terrestrial Radiation):

It is important that the natural radioactivity, which exists in the soils surface, must be investigated because to determine the population's exposure to radiation from building materials, such as soils.

The concentration of potassium usually ranges from 1,000 to 30,000 ppm. It is usually lower but more variable in the basaltic rock region (1,500-20,000 ppm) than in acidic (high concentration of SiO_2) rock regions. For example, in granite rock, the concentration is often about 29,000 ppm.

Radium (^{226}Ra) is the most important radionuclide in the ^{238}U decay chain from the radiobiological viewpoint; therefore, the measurements of ^{226}Ra concentration in building materials are considered as reference in all investigations. Natural radionuclides in building materials may cause both external exposures, caused by their direct gamma radiation, and internal exposure from radon gas.

The concentration of rubidium (which is chemically similar to potassium) is often about 1% of that of potassium. Accordingly, the concentration of radioactivity of rubidium is often about 60% of that of potassium. Rubidium (^{87}Rb), similar to ^{14}C and ^{3}H, emits only soft β-rays and contributes to internal radiation but not to the external radiation but not to the external radiation exposure.

Most of the terrestrial background radiation is due to potassium and to elements of the uranium series (^{238}U to ^{206}Pb), thorium series (^{232}Th to ^{209}Pb), and actinium series (^{235}U to ^{207}Pb). Each of these series consists of many α, β, and γ emitters. The concentration of these radioactive isotopes in the soil and water varies greatly. In certain areas, such as in the coastal areas of Kerala in India, the average dose was found to be 11 mSv/year. In certain areas of southwestern France, in Guarapari in Brazil, and in Ramsar in Iran, the dose rate may be about 17 mSv/year, and in small places within these areas the dose rate may be as high as 170-430 mSv/year. These levels are caused by the higher than usual natural background levels of uranium and thorium isotopes in the soil.

Several studies have been carried out in countries such as Vietnam and Turkey. In Vietnam, the estimated outdoor and indoor annual effective doses to the population were found to be higher than the corresponding values in the rest of the world. The results showed that the radium equivalent activity and the external hazard index of the Vietnam soils surface are lower than the corresponding admissible limits of 370 Bq/kg and 1, respectively. Therefore, Vietnam soil, which is being used as a building material, is secure for the human population. In another study, the natural gamma radioactivity levels of the Samsun city center soil specimens, in Turkey, were calculated. The calculated external hazard index showed the radiation hazard in Samsun to be trivial.

It is important to mention that soil, by being used as building material, can affect a population's exposure to radionuclides; they can also affect the human body by taking food that contains radionuclides; these radionuclides enter the food chain from the deeper soil layers, besides tainting the ground water.

Because of this effect, several surveys have estimated the distribution of natural and synthetic radionuclides in soil profiles and in the surface layer of the soil.

In one survey, the activity-depth profiles of ^{137}Cs were determined in soil specimens from 20 sites in and around the city of Istanbul, Turkey. It was found that the activity concentrations of ^{40}K, ^{232}Th, and ^{226}Ra were distributed uniformly regarding soil depth and the depth distribution of ^{137}Cs generally fitted a linear function.

1.3 Problem of The Study:

Our Country needs a new natural radiologic reading to be a documented as a reference for the coming generations to benefit of it, and the need to determination the radioactivity in soil and rocks which contains radioactive elements to complete the radioactive map of Sudan and to prove that if there are radioactive waste buried in the southern region.

1.4 Objectives:

1.4.1 General Objectives:

The main objective of this study is to measure the concentrations of the radioactive elements associated with radiological hazard in soil, which had been done in Merowe city, northern Sudan.

1.4.2 Specific Objectives:

- To determine the types of radioactive elements in soil.
- To determine the concentration of radioactive elements in soil.
- To construct the radiological map for Merowe city.
- To measure absorbed dose rates.
- To calculate annual effective dose.
- To calculate Radium equivalent activity.
- To calculate external hazard index.
- To calculate Representative Gamma index.

- To compare between the results and other local and global results
- To determine if Merowe city is contaminated or not.

1.5 Thesis layout:

This thesis contains five chapters.

The first chapter is the introduction, the objectives, and the problem of the study.

Then the second chapter propose the literature review and some previous studies in and aboard Sudan.

The third chapter demonstrates materials and methods used.in the fourth chapter the researcher listed the results of the study. Finally in the fifth chapter is the discussion of the results with some limitations, justifications and recommendations.

Chapter Two

Literature Review

2.1 Introduction:

Radioactive decay, also known as nuclear decay or reactivity, is the process by which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays and conversion electrons. A material that spontaneously emits such a radiation is considered radioactive

Najam,Laith A.,Mansour,Hazim.L., Tawfiq, Nada F.,Karim, Mahmood S., (2016), "Measurement of Radioactivity in Soil Samples for Selected Regions in Thi-Qar Governorate-Iraq".J Rad Nucl App

2.2 The Radiation:

The emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization.

2.3 Radioactivity:

Radioactivity is property exhibited by certain types of matter of emitting energy and subatomic particles spontaneously. It is, in essence, an attribute of individual atomic nuclei.

An unstable nucleus will decompose spontaneously, or decay, into a more stable configuration but will do so only in a few specific ways by emitting certain particles or certain forms of electromagnetic energy. Radioactive decay is a property of several naturally occurring elements as well as of artificially produced isotopes of the elements. The rate at which a radioactive element decays is expressed in terms of its half-life; i.e., the time required for one-half of any given quantity of the isotope to decay. Half-lives range from more than 1,000,000,000 years for some nuclei to less than 10−9 second (see below Rates of radioactive transitions). The product of a radioactive decay process—called the daughter of the parent isotope—may it be unstable, in which case it, too, will decay. The process continues until a stable nuclide has been formed.

(https://www.toppr.com/ask/content/concept/introduction-to-radioactivity-210547/)

2.4 Electromagnetic Spectrum: the entire distribution of electromagnetic radiation according to frequency or wavelength starting from radio waves to gamma rays. Radiation exists all around us and is in two forms: ionizing and non-ionizing radiation. The Sun is the main source of electromagnetic radiation.

(https://www.toppr.com/ask/content/concept/introduction-to-radioactivity-210547/)

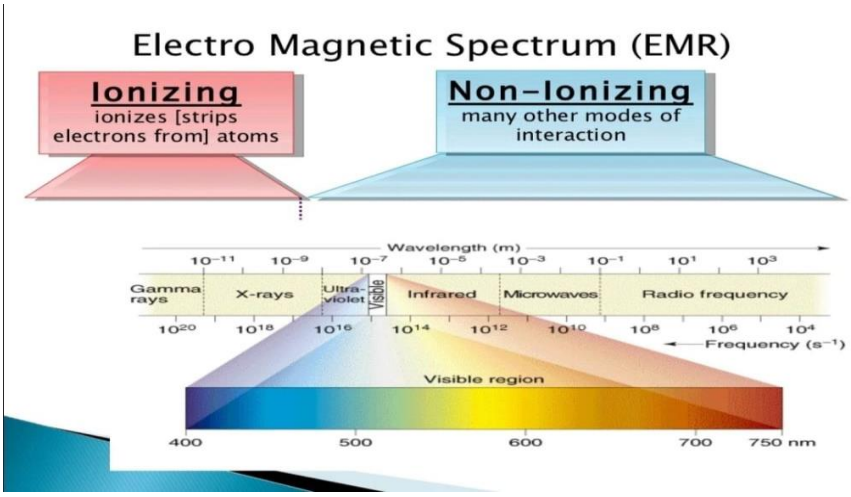

Figure 1: Electromagnetic spectrum range

2.5 Non-ionizing Radiation: Non-ionizing radiation is a form of radiation with less energy than ionizing radiation. Unlike ionizing radiation, non-ionizing radiation does not remove electrons from atoms or molecules of materials that include air, water, and living tissue.

Non-ionizing radiation exists all around us from many sources. It is to the left of ionizing radiation on the electromagnetic spectrum in the figure below.

Examples include:

- Radiofrequency (RF) radiation used in many broadcasts and communications applications
- Microwaves used in the home kitchen
- Infrared radiation used in heat lamps
- Ultraviolet (UV) radiation from the sun and tanning beds.

2.6 Ionizing Radiation:

Ionizing radiation is a form of energy that acts by removing electrons from atoms and molecules of materials that include air, water, and living tissue. Ionizing radiation can travel unseen and pass through these materials. It is on the right side of the electromagnetic spectrum in the figure above.

A familiar example of ionizing radiation is that of x-rays, which can penetrate our body and reveal pictures of our bones.

We say that x-rays are "ionizing," meaning that they have the unique capability to remove electrons from atoms and molecules in the matter through which they pass.

Ionizing activity can alter molecules within the cells of our body. That action may cause eventual harm (such as cancer). Intense exposures to ionizing radiation may produce skin or tissue damage.

Other examples of ionizing radiation include alpha, beta, and gamma rays from radioactive decay.

Ionizing radiation can fall into two categories, natural radiation and man-made radiation .

2.6.1 Ionizing Radiation from Natural Sources

Ionizing radiation that comes from natural sources is typically at low levels. This means that the usual amount of ionizing radiation from natural sources absorbed by our bodies (dose) is small.

These low levels of exposure vary with location, altitude and type of building materials used in home construction. You may also be exposed to the radioactive gas radon if your house or building has a leaky foundation.

In nature, sources of ionizing radiation include:

- Radiation from space (cosmic and solar radiation)
- Radiation from the earth (terrestrial radiation)
- Internal radiation.

  On Earth, we are constantly exposed to low levels of radiation. One natural source of radiation is from space. This type of radiation is called cosmic radiation.

2.6.1.1 Cosmic Radiation:

Cosmic radiation consists of high-energy charged particles, x-rays and gamma rays produced in space. Charged particles react with the earth's atmosphere to produce secondary radiation which reaches the earth.

Cosmic radiation is produced by the stars, including our own sun.

Another form of radiation that comes from our sun is ultraviolet (UV) radiation. UV radiation is not considered cosmic radiation. Unlike cosmic radiation, UV radiation is lower in energy and is considered non-ionizing radiation.

2.6.1.2 Radiation from the Earth (Terrestrial Radiation):

The Earth itself is a source of terrestrial radiation. Radioactive materials (including uranium, thorium, and radium) exist naturally in soil and rock. Essentially all air contains Radon, which is responsible for most of the dose that Americans receive each year from natural background sources. In addition, water contains small amounts of dissolved uranium and thorium, and all organic matter (both plant and animal) contains radioactive carbon and potassium. Some of these materials are ingested with food and water, while others (such as radon) are inhaled. The dose from terrestrial sources varies in different parts of the world, but locations with higher soil concentrations of uranium and thorium generally have higher doses.

2.6.1.3 Internal Radiation:

All people have internal radiation, mainly from radioactive potassium-40 (K^{40}) and carbon-14 (C^{14}) inside their bodies from birth and, therefore, are sources of exposure to others. The variation in dose from one person to another is not as great as that associated with cosmic and terrestrial sources.

Hawpan Chandra Sarkar, Idris Ali, Debasish Paul, Mahbubur Rahman Bhuiyan and Sheikh Mohammad Azharul Islam, 2011, "Measurement of Natural and Artificial Radioactivity in Soil at Some Selected Thanas around the TRIGA Mark-II Research Reactor at AERE, Savar, Dhaka". Journal of Environmental Protection

2.6.2 Ionizing Radiation from Man-made Sources:

Every day, we use Ionizing radiation to help us live healthy lives. Ionizing radiation is found in smoke detectors, used to disinfect medical instruments and blood, and to perform many other tasks in our daily lives. It is also a by-product of nuclear power generation.

Our main exposure to ionizing radiation in manmade sources is using diagnostic medical exams.

Medical exams that use ionizing radiation include:

- X-rays
- CT or CAT (computed tomography) scans
- PET (positron emission tomography) scans
- Fluoroscopy
- Nuclear medicine procedures

Nasir, T.; Al-sulaiti, H. and Regan, P.H.,2012, "Assessment of Radioactivity in some soil samples of Qatar by Gamma –Ray Spectroscopy and the derived dose rates". Pak .J. Sci .ind.res.Ser . A:Phys.sci.

2.7 Radioactive Decays:

- Alpha radiation consists of heavy, positively charged particles emitted by atoms of elements such as uranium and radium. Alpha radiation can be stopped completely by a sheet of paper or by the thin surface layer of our skin (epidermis). However, if alpha-emitting materials are taken into the body by breathing, eating, or drinking, they can expose internal tissues directly and may, therefore, cause biological damage.
- Beta radiation consists of electrons. They are more penetrating than alpha particles and can pass through 1-2 centimetres of water. In general, a sheet of aluminium a few millimetres thick will stop beta radiation.
- Gamma rays are electromagnetic radiation similar to X-rays, light, and radio waves. Gamma rays, depending on their energy, can pass right through the human body, but can be stopped by thick walls of concrete or lead.

- Neutrons are uncharged particles and do not produce ionization directly. But their interaction with the atoms of matter can give rise to alpha, beta, gamma, or X-rays which then produce ionization. Neutrons are penetrating and can be stopped only by thick masses of concrete, water, or paraffin.

Although we cannot see or feel the presence of radiation, it can be detected and measured in the most minute quantities with quite simple radiation measuring instruments.

2.7.1 Radioactive Decay Chains:

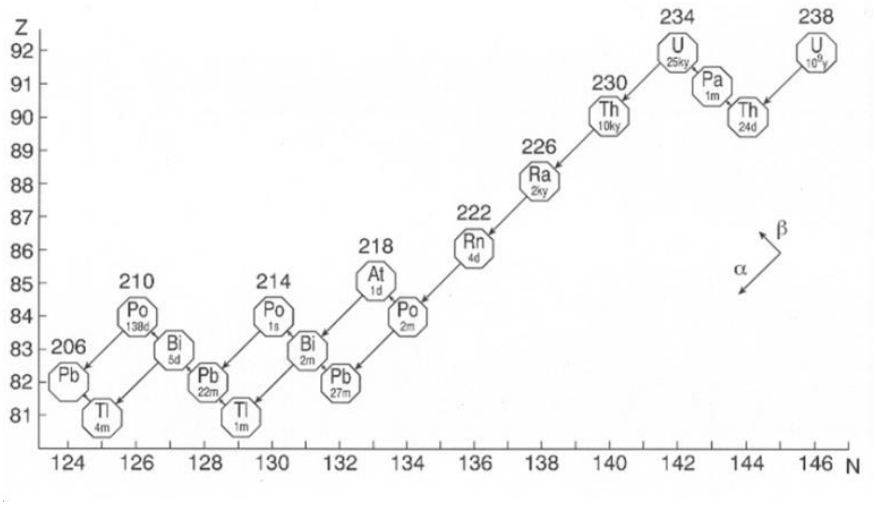

Figure 2: The Uranium-238 decay chain

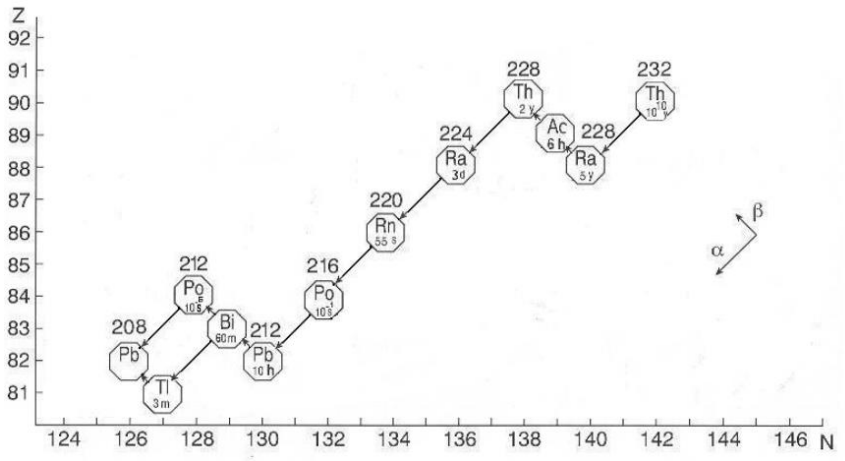

Figure 3: The Thorium-232 decay chain

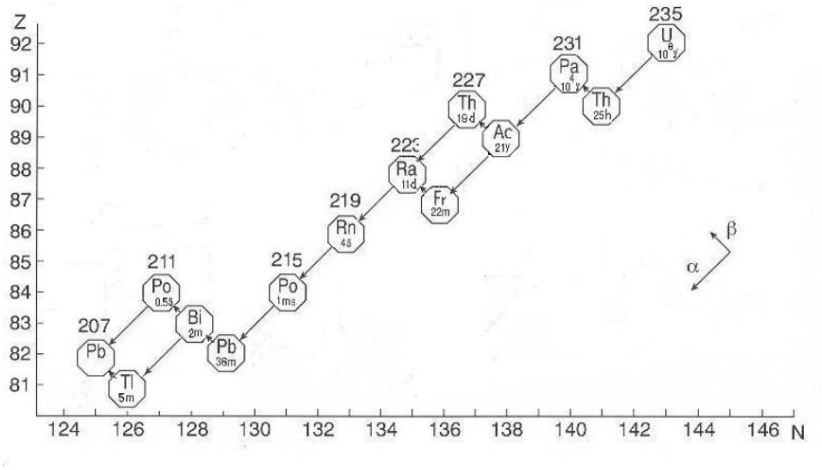

Figure 4: The Uranium-235 Decay chain

2.8 Interaction of Radiation with Matter:

Radiation as a form of energy can be converted to other forms of energies under favourable conditions. Thus, radiation as kinetic energy carried by fast moving particles on approaching matter interacts with the target at the atomic level. Energy is then transferred to the atoms in which ionizations are produced directly (by charged particles alpha, protons and electrons) or indirectly (by neutrons and photons). Probability and mode of interaction determine the dose (energy deposited) in the body, and penetration (how much radiation reaches a target, deep into the body).

Energy is deposited on atoms and molecules; thus, any effect produced will be initially at atomic level. The effect may proceed further and be reflected as changes at molecular, cellular and organ levels.

The incoming radiation, charged particles or electromagnetic radiation, with high velocity, approaches the electron cloud around the nucleus; these particles, being either charged or photons with their associated electromagnetic fields, are expected to interact with either the atom as a particle or with the fields of charges on the nucleus or the electron cloud around the nucleus. Photons will travel along way transferring energy first to electrons

which then deposit energy in matter, electrons with their small mass and charge will lose energy in a large number of collisions along a zigzag route whereas protons heavier in mass will lose energy in a shorter and almost straight-line pass

A beam of photons, of energy hν, interacting with a medium may undergo one or more of three interactions depending on both the energy of the photon and material of the medium. These interactions are demonstrated bellow.

2.8.1 The Photoelectric Effect

The photon may interact with matter depositing all its energy on an atom, the energy may be picked-up by an inner orbit electron and a small part of it used to dislodge (free) the electron from its orbit (this is the energy binding the electron to the nucleus). The remaining part of the acquired energy will be used as kinetic energy and the electron will fly out of the atom, this process is known as photoelectric effect. This will be followed by an outer orbit electron falling in the evacuated electron position emitting the energy difference between the two orbits in the form of a characteristic X-radiation.

2.8.2 The Compton Scattering:

If the photon has higher energy $h\nu_1$, on approaching the atom it can hit one of the loosely bound orbital electrons losing part of the photon energy to the electron which will fly out of the atom (gains kinetic energy E_k) while the photon continues with its remaining energy $h\nu_2$ according to:

$$h\,\nu = h\,\nu_1 + E_k + W$$

the frequency of the incident photon ν_1 is greater than that of the scattered photon ν_2, this process is known as Compton scattering; in this process also, a negligibly small fraction of energy will be used to dislodge the loosely bound outer shell electron.

The probability of this interaction depends on the energy of the incoming photon and the density of electrons in the medium.

2.8.3 Pair Production:

The mass of an electron m_e is equivalent to an energy of 0.511 MeV, so at least theoretically a photon of energy 1.022 MeV can be converted into two electrons of opposite charges. This process occurs in the region of strong electric field close to the nucleus, and to much lesser degree in the field of the orbital electrons. As it increases with field strength it depends on the atomic number of the atom.

$$h\nu \longrightarrow \beta^+ + \beta^-$$

This process is known as pair production, this starts at energies above 1.022 MeV only, and the probability of this process increases with atomic number.

Prof/ Al-atta N O, Lectures Notes

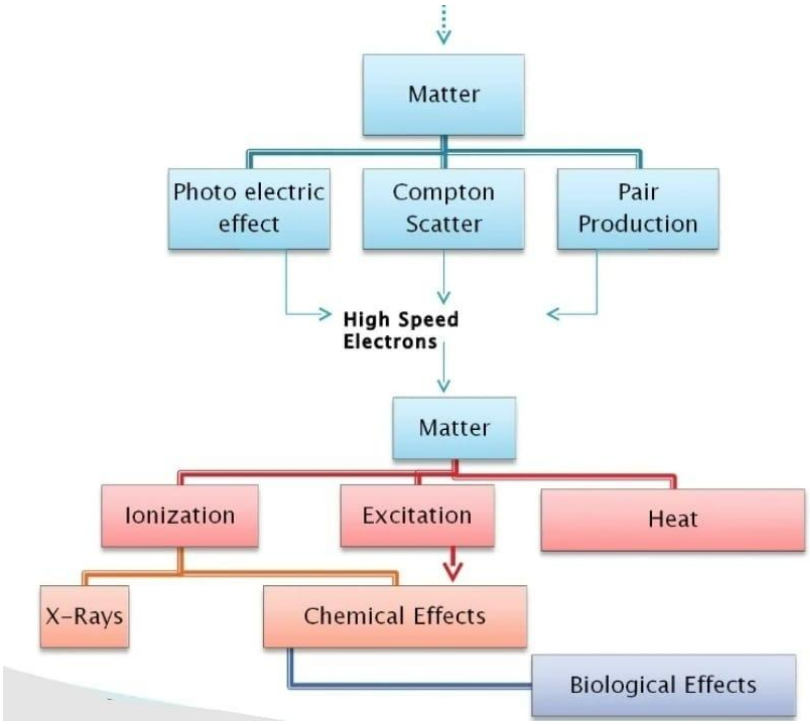

Figure 5: Interactions of radiation with matter:

2.9 Detection of Radiation

The energy loss of particles in matter can be used detect and identify those particles.

There are different types of "detectors":

- Gas-filled counters

- Semi-conductor counters (Germanium, Silicon, NaI….)

- Scintillation counters (Organic & Inorganic: Solid, liquid…)

Prof/ Al-atta N O, Lectures Notes

2.10 Radiation Protection

The main three principles of radiation protection are:

- Shield (using the proper shield of each type of radiation)
- Time (decreasing the exposer time)
- Distance.

2.11 Benefits and Risks of Radiation:

Radiation is a common and valuable tool in medicine, research and industry. It is used in medicine to diagnose illnesses, and in high doses, to treat diseases such as cancer. Also, high doses of radiation are used to kill harmful bacteria in food and to extend the shelf life of fresh produce.

2.12 Previous Studies:

1.M. S. Chandrashekara, S. M. Veda, L. Paramesh had Studies on radiation dose due to radioactive elements present in ground, water and soil samples around Mysore csome ity, India

They found out the following, ^{226}Ra activity concentration in water samples varies from 0.28 to 189 mBq l−1with a geometric mean (GM) of 4.75 mBq l−1and ^{222}Rn concentration in ground water varies from 4.25 to 435 Bq l−1 with a GM of 25.9 Bq l−1. The GM of inhalation and ingestion doses due to ^{222}Rn in water is 65.2 and 5.43, μSv y−1,

respectively. The measured GM gamma dose rate in air is 85.4 nGy h–1 and absorbed dose rate estimated from the measured activity of radionuclides is 92.6 nGy h–1

2.Valter Antonio BecegatoI, Francisco José Fonseca FerreiraII and William César Pollonio MachadoIII had measured the concentration of radioactive elements (U, Th and K) derived from phosphatic fertilizers in cultivated soils ,the results showed that the radionuclide concentrations in more clayey soils were higher than in more sandy soils, mainly as a function of a higher adsorption capacity of the former. For the area where human activity predominated, the average contents of K, U and Th were respectively 54.75; 10.22 and 7.27 Bq/Kg, significantly higher than those for the area where no fertilizers were used (34.15 Bq/Kg K; 1.69 Bq/Kg eU, and 5.36 Bq/Kg eTh). Variations in the radionuclide concentrations were also observed in various fertilizer formula used in soybean and wheat crops.

3.Laith A.Najam, Shaher A,Younis and Fouzey H,Kithah studied the natural radio-activities due to presence of Ra^{226}, Th^{232} and K^{40} in soil of Nineveh zone, Nineveh province, Iraq were measured by using gamma-ray spectrometry based on high-purity germanium detector. The specific activity of soil samples ranged from 16.21 to 38.83 Bq/kg with an average of value of 32.52±6.48 Bq/kg, 8.53 to 28.37 Bq/kg, with an average of 20.305.36 Bq/kg, 236.03 to 613.11 Bq/kg with an average of 378.93± 123.29 Bq/kg and 2.18 to 17.92 Bq/kg with an average of 8.17± 5.55 Bq/kg for Ra^{226} ,Th^{232}, K^{40} and Cs^{137} respectively. The study also examine some radiation hazard indices such as Radium equivalent activity (R_{aeq}), Absorbed gamma dose rate (D), External hazard index(H_{ex}) Internal hazard index (H_{in}) and gamma index (I_{γ}) these calculated hazard indices to estimate the potential radiological health risks in soil. The Radium equivalent activity average (R_{aeq}) was less than the permitted value (370 Bq/kg) the average absorbed dose rate value also less than the permissible limit of 55 nGy/h. the external hazard index, internal hazard index and gamma index of soil samples were less than unity.

4.Moawia Mohammed Elmahdi and Adam Khatir Sam, assessed the terrestrial gamma radiation in sinnar state,the Results have shown insignificant variation in activity

concentrations of Ra-226, Th-232 and K-40. They all live within the range of 25- 50 Bq/Kg for the Th-232, 12-20Bq/Kg for Ra-226 and 148-170 Bq/Kg for K-40.

Average values were 38.01± 8.21Bq/Kg (Th-232), 17.21± 2.41 Bq/Kg (Ra-226), 177.44 ± 19.08 Bq/Kg for (K-40).

5. Adil Aljezoly Mohammed Ali and prof Nadia Omer Al-Atta measured the natural radioactive elements concentration in Wadi halfa. They were found that the mean effective dose in igneous rocks regions was 0.249μsv/h, in sedimentary rocks regions was 0.194 μSv/h, metamorphic rocks regions was 0.14μSv/h and in others was 0.224 μSv/h.

6.Esraa Hashim Ali and Nadia Omer Al-Atta 18easured the activity concentrations of natural radioactive elements in soil in karima city. The result showed that the activity ranged from 7.05 to 19.2 Bq Kg^{-1} for ^{226}Ra, from 9.7 to 55 Bq Kg^{-1} for ^{232}Th, and 59 to 378 Bq $Kg^{-1}$for ^{40}K. The average absorbed dose of the terrestrial natural existing radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were found to be 22.903 $nGyh^{-1}$. The evaluated annual effective dose is 28.08 μSvy^{-1}. The mean absorbed dose is 22.9 $nGyh^{-1}$, and the mean radium equivalent activity is 50.31 Bq Kg^{-1}. The external hazard index is 0.135877 which is less than one. The representative gamma index was also less than one.

Chapter Three

Materials and Methods

3.1 Introduction

The study took a place in town in Northern State, Sudan, near Karima Town, about 330 kilometres (210 mi) north of Khartoum with coordinates 18°28’47.9”N 31°48’56.3”E

Merowe (where study took a place) is a border the Nile and is the site of the Merowe Dam project.

Merowe is an ancient city on the east bank of the Nile about 6 km north-east of the Kabushiya station near Shendi, Sudan, approximately 200 km north-east of Khartoum. Near the site are a group of villages called Bagrawiyah. This city was the capital of the Kingdom of Kush for several centuries. The Kushitic Kingdom of Merowe gave its name to the Island of Meroë, which was the modern region of Butana, a region bounded by the Nile (from the Atbarah River to Khartoum), the Atbarah and the Blue Nile.

The Kingdom of Kush which housed the city of Meroe represents one of a series of early states located within the middle Nile. It is one of the earliest and most impressive states found south of the Sahara. Looking at the specificity of the surrounding early states within the middle Nile, one’s understanding of Meroe in combination with the historical developments of other historic states may be enhanced through looking at the development of power relation characteristics within other Nile Valley states.

The site of the city of Meroe is marked by more than two hundred pyramids in three groups, of which many are in ruins. They have the distinctive size and proportions of Nubian pyramids.

In June 2011, the Archaeological Sites of Meroe were listed by UNESCO as World Heritage Sites.

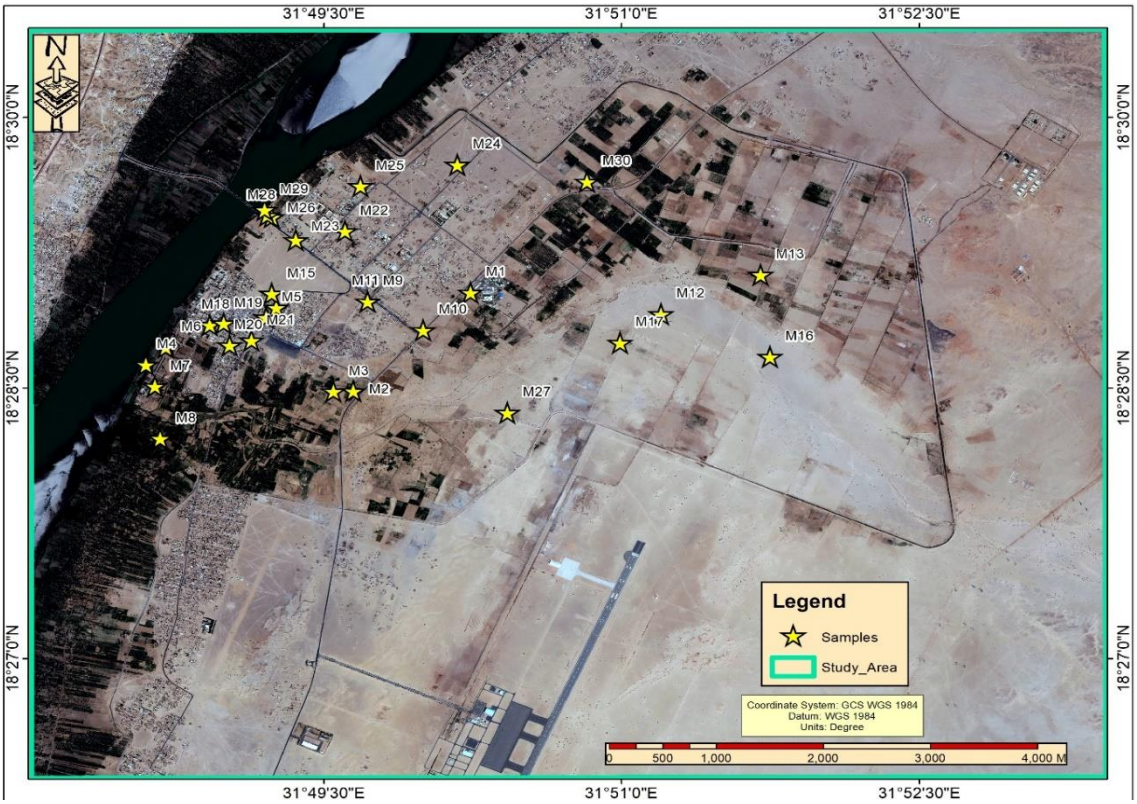

Figure 3.1: Merowe City Location

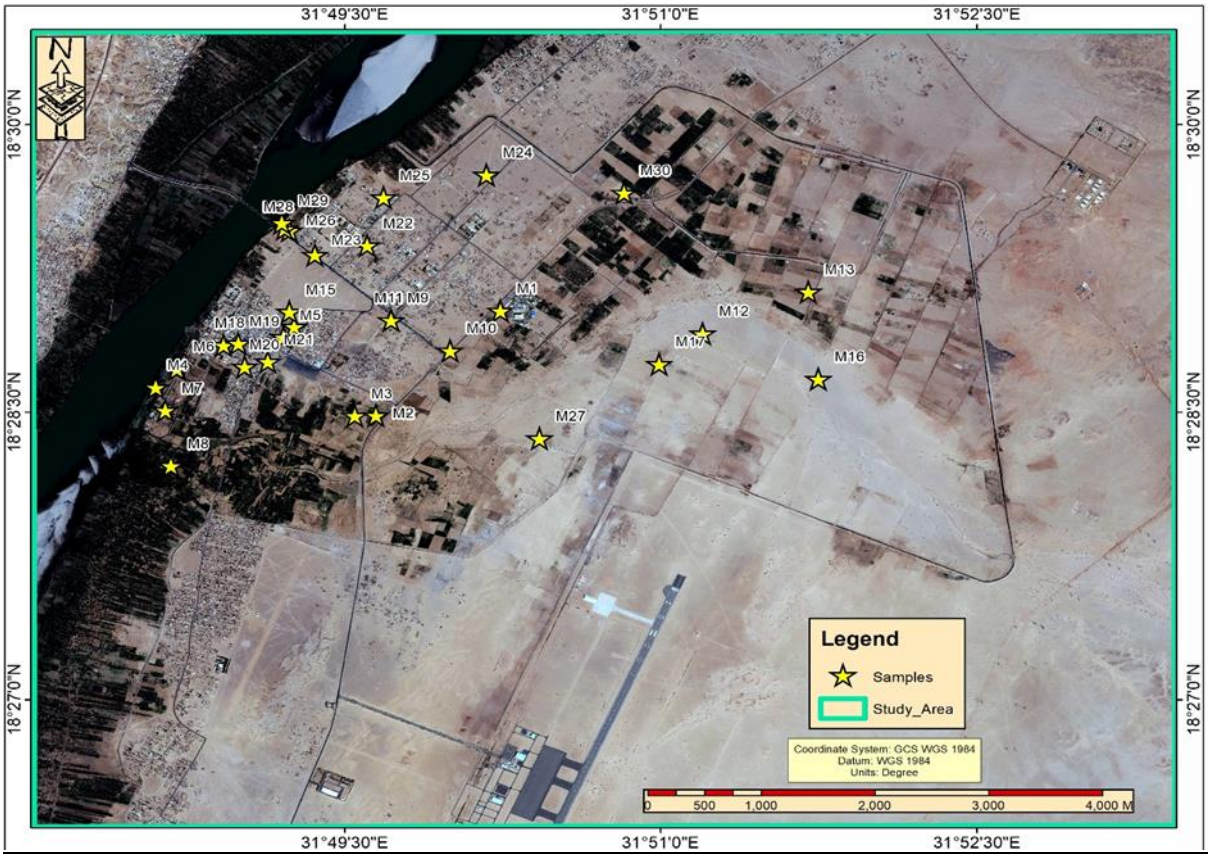

Figure 3.2: The sample's locations

3.2 Materials Used:

- Spade and auger (screw or tube or post hole type)
- Khepri
- Core sampler
- Sampling bags
- Plastic tray or bucket
- Meter
- Scales
- GPS
- Geologist's hammer
- Compass
- High Purity Germanium (HPGe) Detectors:

3.3 The Method of Work:

The process of measuring the concentrations of radioactive elements in the soil was carried out through sequential and organized processes that we will discuss in detail in this chapter, starting with the process of selecting the areas from which samples were collected, passing through the process of preparing those samples for the examination process and the stages of drying and storing them, and ending with the process of conducting tests on those samples using he system of high purity germanium (HPGe) detector, which we will discuss in details.

We have faced great difficulty in the process of choosing the areas from which we will take soil samples for the purpose of making measurements on them, due to the difficulty of the legal procedures that we have met to obtain the necessary approvals and official books, to allow us to conduct the collection process

We faced some difficulties due to the ruggedness of the land and the difficulty of reaching all areas of sample collection

3.3.1 Collecting of Samples:

Using a GPS system, the locations were recorded, where individual samples were taken from.

The samples had been collected selected areas within the city. From the riverbanks, Merowe Medical city, Merowe tourist village, Merowe dam , the graveyard ….etc

The samples had been collected from a depth of 40 cm using a meter. After that the samples were cleaned and collected into a clean bucket, mixed well, and put into a clean plastic bag, the weight of each sample was one kilogram.

All samples were labelled clearly as M1, M2, M3…..etc to avoid mixing.

3.3.2 Preparation of Samples

After collecting the samples, they were brought into the laboratory of the Radiation safety institute, the samples had been cleaned of gravel and suspended plant residues, and then dried them from moisture by placing them in a thermal oven at a temperature of 110℃ for 24 hours, and then grinding them well using a mortar to be sieved using a fine sieve with a mesh diameter of 2 mm to obtain homogeneous samples.

3.3.3 High Purity Germanium Device (HPGe):

Specific activities of the radionuclides were determined by using the gamma ray spectrometry method using high purity Germanium (HPGe), P-type coaxial detector, GCD30185x model with 37% relative Efficiency and multi-channel analyser unit with 16384 channels, Manufactured by Baltic scientific instrument company.

The energy resolution (full width at half maximum) of this detector is 1.95 Kev for gamma energy line at 1332.520 Kev due co^{60}.

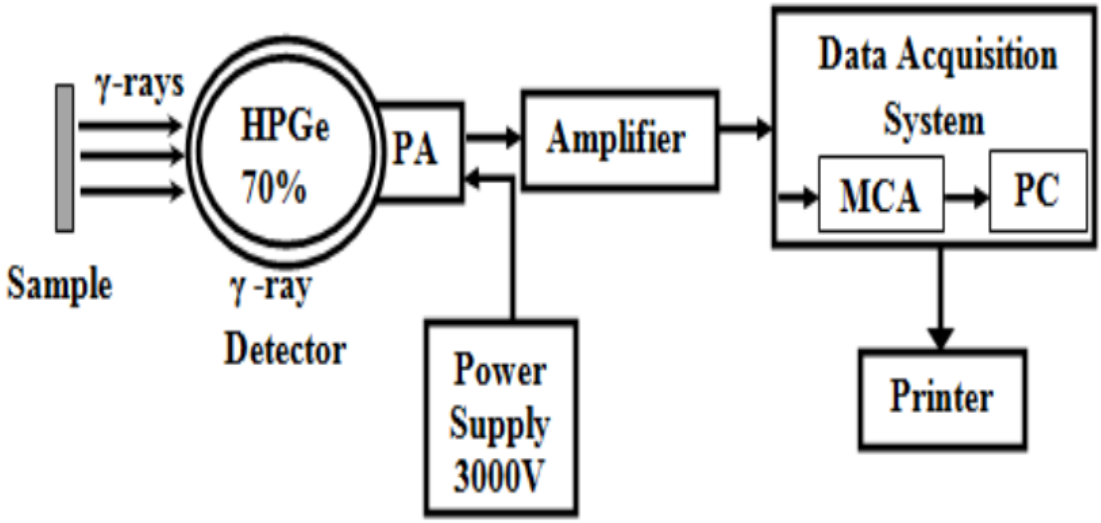

Figure 3.3: Possessing the samples using high purity Germanium detector (HPGe)

Figure 3.4: Gamma ray spectroscopy system with high purity germanium detector (HPGe)

3.3.4 Absorbed Dose Rates Calculation:

Dose rate was calculated using the conversion constants:

0.0417, 0.462 and 0.604 nGy/h, respectively, for ^{40}K, ^{226}Ra, and ^{232}Th published in UNSCEAR (2008) report from the equation:

$$D = (0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{k}) \quad (1)$$

Where A_{Ra} , A_{Th} , A_{k} are the average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

3.3.5 Annual Effective Dose Rates Calculation:

The absorbed dose rate was converted into annual effective dose equivalent by using a conversion factor of 0.7Sv Gy^{-1} recommended by the UNSCEAR 2000 report, and 0.2 for the outdoor occupancy factor. The effective dose due to natural activity in the soil was calculated by:

Effective dose, E= Dose rate,

$$D\ (nGyh^{-1}) \times 8760(hy^{-1}) \times 0.2 \times 0.7Sv\ Gy^{-1} \times 10^{3} \quad (2)$$

3.3.6 Radium Equivalent Activity Calculation:

Radionuclides of ^{226}Ra, ^{232}Th and ^{40}K are not homogeneously distributed in soil. The inhomogeneous distribution from these naturally occurring radionuclides is due to disequilibrium between ^{226}Ra and its decay products. For uniformity in exposure estimates, the radionuclides concentrations have been defined in terms of radium equivalent activity (Ra_{eq}) in $BqKg^{-1}$. This allows comparison of the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K according to Beretka and Mathew (Beretka, J. and Mathew, P.J) as follows

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_{K} \quad (3)$$

Where A_{Ra} , A_{Th} and A_{k} are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

3.3.7 External Hazard Index Calculation:

The external hazard index (H_{ex}) is the indoor radiation dose rate due to the external exposure to gamma radiation in construction materials of dwellings was calculated by: (Lu, X.and Xiolan, Z)

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \qquad (4)$$

Where A_{Ra} , A_{Th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

3.3.8 Radioactivity Level Index Calculation:

The radioactivity level index Iγ is used to monitor radiation inside the human body and to compute the risky level of radionuclides in the human body when exposed to an amount of indoor or outdoor annual effective dose of γ-radiations from radioactive nuclides in soil. The estimated value of Iγ should be less than or equal to one to make sure the soil environment is hazard-free.

Values of Iγ were calculated according to the following formula (S.Issa, M. Uosif, and R, Elsaman):

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \quad (5)$$

Chapter Four

Results

Table 4.1: Sample's Locations:

Thirty soil samples had been taken from different locations, the table below displays the coordinates of these locations

Samples	Latitudes	longitudes
M1	18°29'01.9"N	31°50'14.3"E
M2	18°28'29.1"N	31°49'38.9"E
M3	18°28'29.0"N	31°49'32.8"E
M4	18°28'37.9"N	31°48'36.1"E
M5	18°28'53.5"N	31°49'12.5"E
M6	18°28'43.7"N	31°48'42.1"E
M7	18°28'30.7"N	31°48'38.8"E
M8	18°28'13.3"N	31°48'40.5"E
M9	18°28'58.9"N	31°49'43.2"E
M10	18°28'49.4"N	31°50'00.0"E
M11	18°28'58.9"N	31°49'43.2"E
M12	18°28'54.7"N	31°51'11.9"E
M13	18°29'07.8"N	31°51'42.0"E
M14	18°28'56.8"N	31°49'15.5"E
M15	18°29'01.5"N	31°49'14.2"E
M16	18°28'40.5"N	31°51'44.9"E
M17	18°28'45.2"N	31°50'59.5"E
M18	18°28'51.1"N	31°48'55.4"E

Samples	Latitudes	longitudes
M19	18°28’51.6”N	31°48’59.6”E
M20	18°28’44.3”N	31°49’01.5”E
M21	18°28’45.9”N	31°49’08.0”E
M22	18°29’22.3”N	31°49’36.3”E
M23	18°29’19.3”N	31°49’21.5”E
M24	18°29’44.4”N	31°50’10.3”E
M25	18°29’37.3”N	31°49’41.0”E
M26	18°29’27.0”N	31°49’14.2”E
M27	18°28’21.9”N	31°50’25.4”E
M28	18°29’27.5”N	31°49’12.8”E
M29	18°29’29.4”N	31°49’12.0”E
M30	18°29’38.8”N	31°50’49.5”E

Table 2: Activity Concentrations of Radioactive Elements in Soil Samples Measured in (Bq/Kg)

The following results had been obtained after testing the samples

Samples	Ra-226 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
M1	15.7	40.1	807
M2	16.2	24.5	540
M3	28.4	53.5	541
M4	10.7	12.3	347
M5	16.5	22.2	438
M6	13.7	17.2	357
M7	12.4	18.7	405
M8	13.7	22.4	373
M9	25.2	39.8	649
M10	28.6	43.5	590
M11	15.6	26.6	495
M12	24.6	42.2	651
M13	21.6	35.1	510
M14	23.4	40.1	807
M15	15.6	21	466
M16	21.6	35.1	510
M17	12.2	19	226
M18	17.1	23.8	550

M19	15.2	17.9	374
M20	16.3	23	641
M21	21.9	29.8	516
M22	13.1	23.6	148
M23	16.3	23.3	543
M24	23.1	34.7	506
M25	24.9	37.5	729
M26	20.6	32.8	489
M27	19.3	44.5	508
M28	21.7	28.8	547
M29	17.3	25.3	259
M30	14.6	41.1	491

Quantity	Ra-226 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
Average	18.57	29.98	500.4333333
S.D	4.914029879	10.1123823	152.1668058
Min	10.7	12.3	148
Max	28.6	53.5	807
Median	17.1	28.8	508

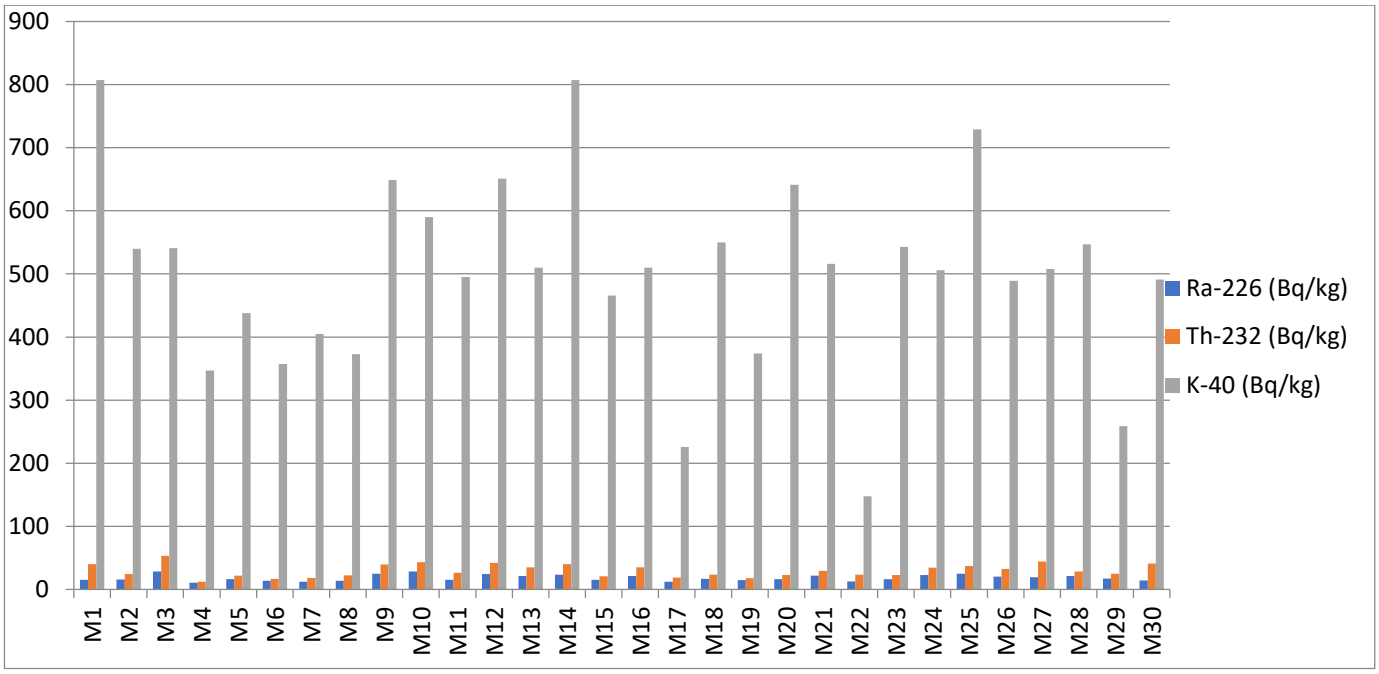

Figure 8: Distribution of Ra^{226}, Th^{232} and K^{40} in soil samples

Table 3: The Absorbed Dose Rates (nGy/h)

Using equation, No 1 the following results had been obtained

Samples	D (nGy/h)
M1	65.1257
M2	44.8004
M3	67.9945
M4	26.8425
M5	39.2964
M6	31.6051
M7	33.9121
M8	35.4131
M9	62.7449
M10	64.0902
M11	43.9151
M12	64.0007
M13	52.4466
M14	68.6831
M15	39.3234
M16	52.4466
M17	26.5366
M18	45.2104
M19	33.4298

M20	48.1523
M21	49.6342
M22	26.4782
M23	44.2469
M24	52.7312
M25	64.5531
M26	49.7197
M27	56.9782
M28	50.2305
M29	34.0741
M30	52.0443

Quantity	D (nGy/h)
Average	47.55533
S.D	12.99074979
Min	26.4782
Max	68.6831
Median	48.1523

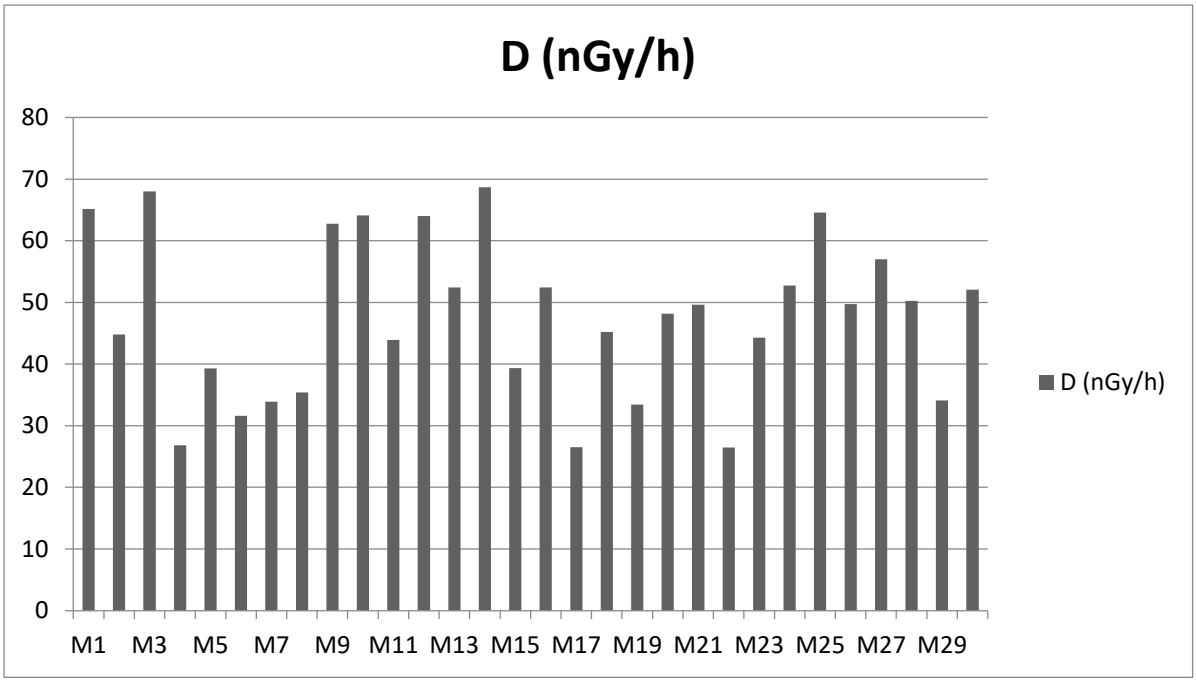

Figure 9: The distribution of the dose Rate in the soil samples

Table 4: Annual Effective Dose Rates (µSv/y):

Using equation, No 2 the following results had been obtained

Samples	AEDE (µSv/y)
M1	79.87
M2	54.94
M3	83.39
M4	32.92
M5	48.20
M6	38.76
M7	41.59
M8	43.43
M9	76.95
M10	78.60
M11	53.86
M12	78.49
M13	64.32
M14	84.23
M15	48.22
M16	64.32
M17	32.54
M18	55.45
M19	40.99

M20	59.05
M21	60.87
M22	32.47
M23	54.26
M24	64.67
M25	79.17
M26	60.98
M27	69.88
M28	61.60
M29	41.79
M30	63.83

Samples	AEDE (µSv/y)
Average	58.32
S.D	15.93
Min	32.47
Max	84.23
Median	59.05

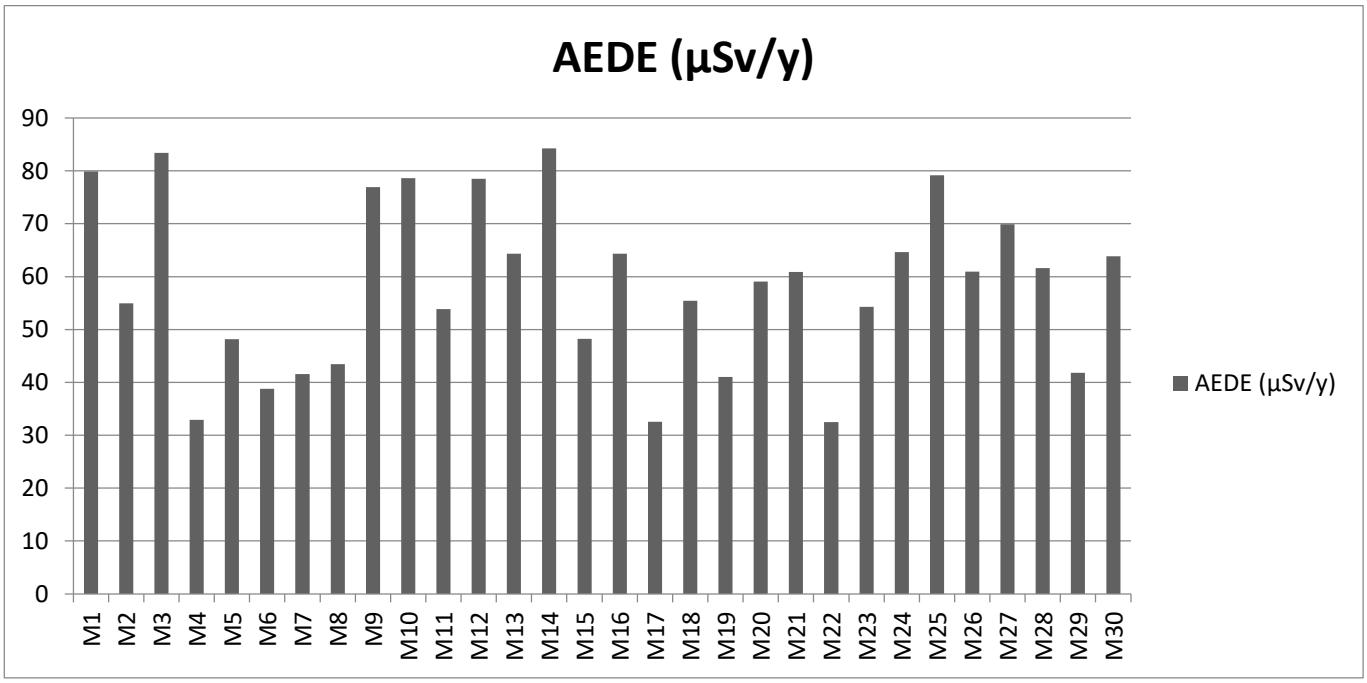

Figure 10 : Distribution of the annual effective dose in soil samples

Table 5: Radium Equivalent Activity (Bq/Kg):

Using equation, No 3 the following results had been obtained

Samples	Ra_{eq} (Bq/kg)
M1	135.18
M2	92.81
M3	146.56
M4	55.02
M5	81.97
M6	65.78
M7	70.32
M8	74.45
M9	132.08
M10	136.23
M11	91.75
M12	135.07
M13	111.06
M14	142.88
M15	81.51
M16	111.06
M17	56.77
M18	93.48
M19	69.59

M20	98.54
M21	104.24
M22	58.24
M23	91.43
M24	111.68
M25	134.65
M26	105.15
M27	122.05
M28	105.00
M29	73.42
M30	111.18

Quantity	Ra_{eq} (Bq/kg)
Average	99.97
S.D	27.51
Min	55.01
Max	146.56
Median	99.97

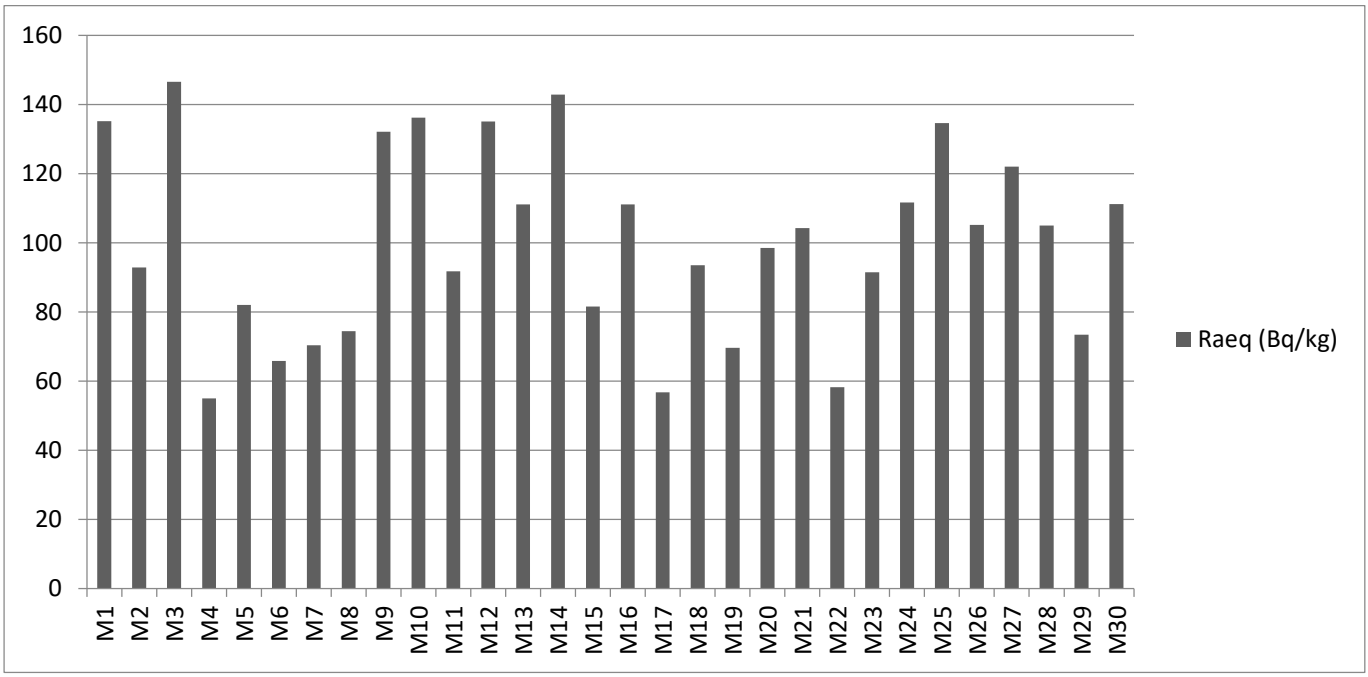

Figure 11: Distribution of radium equivalent activity

Table 6: External Hazard Index (H_{ex})

Using equation, No 4 the following results had been obtained

Samples	H_{ex}
M1	0.36
M2	0.25
M3	0.39
M4	0.14
M5	0.22
M6	0.18
M7	0.19
M8	0.20
M9	0.36
M10	0.37
M11	0.28
M12	0.36
M13	0.29
M14	0.38
M15	0.22
M16	0.29
M17	0.15
M18	0.25
M19	0.18

M20	0.26
M21	0.28
M22	0.16
M23	0.25
M24	0.30
M25	0.36
M26	0.28
M27	0.33
M28	0.28
M29	0.20
M30	0.30

Quantity	H_{ex}
Average	0.757
S.D	0.20
Min	0.42
Max	1.09
Median	0.76

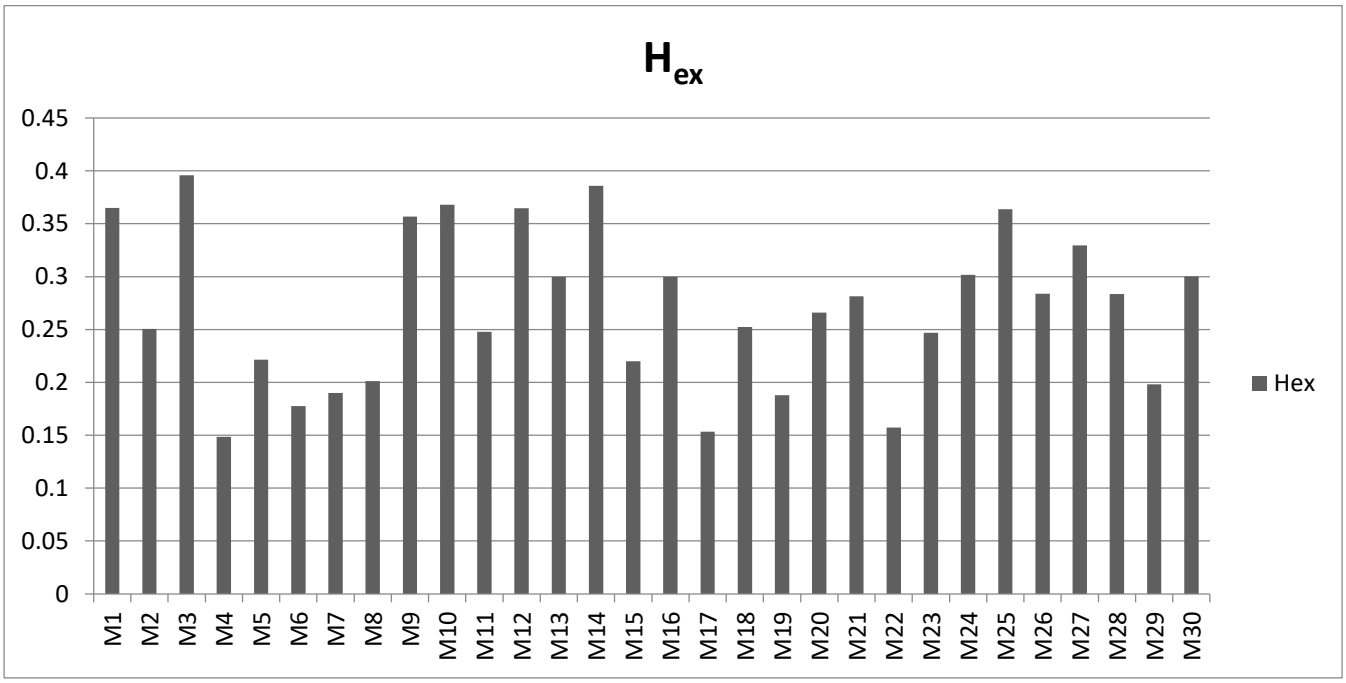

Figure 12 : External hazard index

Table 7 : Representative Gamma Index $I_{\gamma r}$:

Using equation, No 5 the following results had been obtained

Samples	$I_{\gamma r}$
M1	1.04
M2	0.71
M3	1.086
M4	0.42
M5	0.62
M6	0.50
M7	0.54
M8	0.564
M9	0.99
M10	1.20
M11	0.70
M12	1.02
M13	0.84
M14	1.96
M15	0.62
M16	0.83
M17	0.42
M18	0.72
M19	0.53

M20	0.77
M21	0.79
M22	0.42
M23	0.70
M24	0.84
M25	1.027
M26	0.79
M27	0.91
M28	0.79
M29	0.54
M30	0.84

Quantity	$I_{\gamma r}$
Average	0.757
S.D	0.21
Min	0.42
Max	1.096
Median	0.27

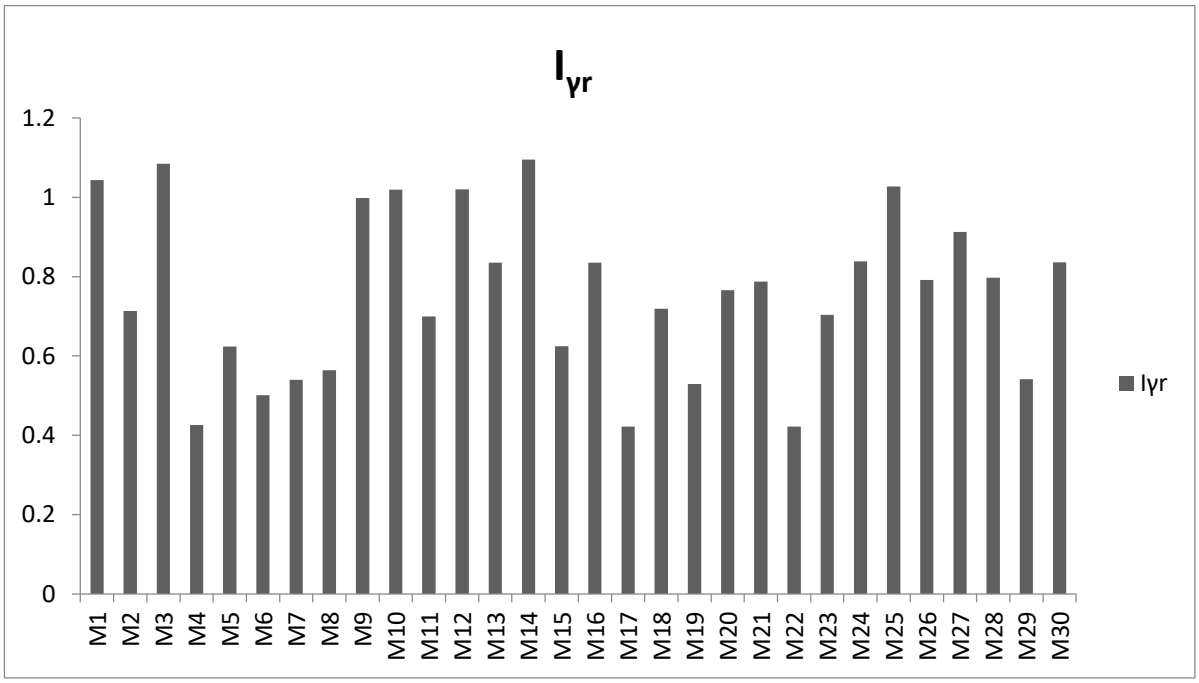

Figure 13: Representative gamma index

Table 8: Comparison between the values obtained in this study and other local studied

	$A_{Ra\ Bq/Kg}$	A $_{Th\ Bq/Kg}$	A $_{k\ Bq/Kg}$	D(nGy/h)	AEDE µsv/y	Ra_{eq}	H_{ex}	$I_{\gamma r}$
Ave	18.57	29.98	500.43	32.95	58.322	99.975	0.135877	0.757
Stdv	4.914	10.110	152.167	12.07	15.932	27.516	0.03825	0.208
Min	10.7	12.3	148	22.903	32.472	55.008	0.27142	0.422
Max	28.6	53.5	807	6.260	84.233	146.562	0.07126	1.095
(Karima)	11.58	20.08	130.1	22.90	28.08	50.31	0.136	03.64
(Sinner)	17.21±2.41	38.01±8.21	177.44±19.08	38.08±7.02	47.59±6.07	—	—	—
(Dakka)	55.25±4.68	125.27±5.81	497.91±43.83	124.12±7.59	152.23±9.31	269.24 ±16.06	0.601	0.601

عادل الجزولي، نادية عمر العطا. قياس تراكيز العناصر المشعة الطبيعية بمنطقة وادي حلفا.مجلة العلوم التطبيقية.2015.

اسراء هاشم ، نادية عمر العطا. قياس تراكيز العناصر المشعة الطبيعية كريمة 2020.

Table 9: Comparison Between the values obtained in different countries

Country	Activity Concentrations of radioactive elements in Soil samples measured in (Bq/Kg)			
	^{238}U	^{232}Th	^{40}K	^{226}Ra
Sulaimany-Iraq	83.33	19.14	284.86	---
Najaf-Iraq	77.33	9.36	426.31	---
Mosul-Iraq	---	12.55	242.42	40.71
Turkey	55.42	22.86	1318	32
Yemen	---	36.26	358.12	30.41
Russia	---	33.03	557.40	26.89
Saudi Arabia	---	12.3	535	9.5
Himalaya-India	---	69	792	64
Nigeria	55.3	26.4	505.1	---
Present study	41.24	21.52	326.74	33.55
World average	33	45	412	32

Najam A, Younis A, and H,Kithah (2016)The natural radio-activities due to presence of Ra^{226}, Th^{232} and K^{40} in soil of Nineveh zone,

Chapter Five

Discussion of the Results

5.1 Interpretation of The Results

The results obtained during our study, using High Purity Germanium (HPGe) Detectors, showed that the activity of Radium (Ra^{226}) measured with High Purity Germanium (HPGe) detectors was slightly higher than the global average in the study areas where the average in Merowe was is 18.57 Bq/Kg, the global average is 15.95 Bq/Kg the local average about 15 Bq/kg.

The activity of Thorium (Th^{232}) is 29.98 Bq/kg where the global average is 125 Bq/kg and the local average is 38.01 ±8.21 Bq/kg.

The activity of Potassium (K^{40}) is 500.43 Bq/kg where the global average is 497 Bq/kg and the local average is about 177 ±19.08 Bq/kg.

The highest activity of Radium (Ra^{226}) was found in sample M10 (28.6 Bq/kg) and the lowest was found in sample M4 (10.7 Bq/kg)

The highest activity of Thorium (Th^{232}) was found in sample M3 (53.5 Bq/kg) and the lowest was found in sample M4 (12.3 Bq/kg)

The highest activity of Potassium (K^{40}) was found in sample M14 (807 Bq/kg) and the lowest was found in sample M22 (148 Bq/kg)

The calculated dose rate evaluated in table 3 was found in the range of 26.48 to 68.68 nGy/h.

The calculated annual effective dose evaluated in table 4, was found in the range of 32.47 to 84.23 µSv/y.

The calculated radium equivalent activity in table 5 was found in the range of 55.01 to 146.56 Bq/kg

The calculated external hazard index in table 6 was found in the range of 0.42 to 1.01.

The calculated representative gamma index Iγr in table 7 was found in the range of 0.42 to 1.01.

5.2 Conclusion:

• The activity of Potassium (K^{40}) measured with High Purity Germanium (HPGe) detectors were slightly higher than the global average

• Merowe is not contaminated, however the concentration of radioactive elements is within the normal ranges and the concentration of Potassium K^{40} maybe due to the existence of biological waste products.

• The percentage of the activity of Radium (Ra^{226}) is 64.9%

• The percentage of the activity of Thorium (Th^{232}) is 56%

• The percentage of the activity of Potassium (K^{40}) is 61.9%

5.3 Recommendations:

• Further studies should be carried out in other forms samples such as animal bones, plant roots and rocks and link that with other readings.

• Compare between these studies.

• Samples should be taken from various depths.

• It would be beneficial if the government paid more attention to avoid biological radiation related hazards.

References

Moawia Mohammed Elmahdi and Adam Khatir Sam, (2006):assessment of the terrestrial gamma radiation in sinnar state.

Mehra, R. and Singh, M.,2012, "Estimation of radiological risk due to concentration of ^{238}U,^{226}Ra, ^{232}Th and ^{40}K in soils of different geological origins in northern India".Turk J Phys

S. Issa, M. Uosif, and R. Elsaman, " Gamma radioactivity measurements in Nile river sediment samples." Turkish journal of engineering environmental sciences.

UNSCEAR., (2000) Exposure from natural radiation sources. United Nations Scientific committee on the effects of Atomic Radiation. Report to general assembly Annex B exposure from natural radiation sources, United Nations, New York.

Shawpan Chandra Sarkar, Idris Ali, Debasish Paul, Mahbubur Rahman Bhuiyan and Sheikh Mohammad Azharul Islam, 2011, "Measurement of Natural and Artificial Radioactivity in Soil at Some Selected Thanas around the TRIGA Mark-II Research Reactor at AERE, Savar, Dhaka". Journal of Environmental Protection

Nasir, T.; Al-sulaiti, H. and Regan, P.H.,2012, "Assessment of Radioactivity in some soil samples of Qatar by Gamma –Ray Spectroscopy and the derived dose rates". Pak .J. Sci .ind.res.Ser . A:Phys.sci.

Rashed M.Yousuf and Kamal O.Abdullah ,2013,"Measurement of natural radioactivity in soil collected from the Eastern of Sulaimany Governorate in Kurdistan –Region ,Iraq" ,ARPN J. of sciences and Technology

https://www.toppr.com/ask/content/concept/introduction-to-radioactivity-210547/

عادل الجزولي، نادية عمر العطا. قياس تراكيز العناصر المشعة الطبيعية بمنطقة وادي حلفا.مجلة العلوم التطبيقية.2015.

اسراء هاشم ، نادية عمر العطا. قياس تراكيز العناصر المشعة الطبيعية كريمة 2020.