Sudan University of Science and Technology
College of graduate studies

Measurement Of Radioactivity Concentrations In Soil Samples From Karima City, Sudan

قياس تراكيز النشاط الإشعاعي في عينات تربة من مدينة كريمة- السودان

A thesis submitted for partial fulfillment ofthe requirement for master Degree in nuclear physics

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قال تعالى:

(اقرَأ وربُّك الأكرَمُ)..

العلق.. الآية (3)

Dedication:

To my beloved family..

For all who encourage me to fly toward my dreams…

To my great teacher, prof. Nadia Omer..

To my country.. Sudan

Abstract

This study aimed to measure the activity concentrations of natural radioactive elements in soil in karima 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 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 $BqKg^{-1}$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.

The results of this study were compared with other studies and found that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K were the lowest.

ملخص الدراسة

هدفت هذه الدراسة إلى قياس النشاط الإشعاعي للعناصر المشعة الطبيعية في التربة بمدينة كريمة . 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 بين 7.05 إلى 19.2 بيكرل/كجم لـ^{226}Ra، ومن 9.7 إلى 55 بيكرل/كجم لـ ^{232}Th، ومن 59 لـ 378 بيكرل/ كجم لـ^{40}K.

تم قياس الجرعة الفعالة السنوية ووجد أنها تساوي 28.08 μSvy^{-1} ، ومتوسط الجرعة الممتصة 22.9 $nGyh^{-1}$. أما مكافئ الراديوم وجد أنه يساوي 50.31 بيكرل/كجم، أيضاً تم قياس مستوى الخطورة الخارجي ووجد أنه يساوي0.135877>1. أيضاً دليل خطورة قاما وجد أنه أقل من 1.

تمت مقارنة هذه الدراسة مع دراسات أخرى ، ووجد أن تراكيز ^{226}Ra, ^{232}Th and ^{40}K كانت الأقل.

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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:

Radiation is part of nature. All living creatures from the beginning of time have been and are still being exposed to radiation.

The radiation to which human population is exposed comes from many diverse sources. Some of these sources are natural; others are the result of human activities.

The radiation from natural sources include cosmic radiation, external radiation from radionuclides in earth's crust and internal radiation from radionuclides inhaled or ingested and retained in the body.

The magnitude of these natural exposures depends on geographical location and on some human activities.

Height above sea level affects the dose rate from cosmic radiation. Radiation from the ground depends on the local geology, and the dose from radon, which seeps from the ground into houses (Gur et al, 2001).

A significant part of the total dose contribution in the form of natural sources comes from terrestrial gamma nuclides (UNSCEAR, 2000) .only nuclides with half-lives comparable with the age of the earth or their corresponding decay products, existing in the terrestrial materials, such as ^{40}k , ^{238}U and ^{232}Th radionuclides are of the great interest . abnormal occurrences of uranium and its decay products in rock and soil are the main sources of high natural background areas that have been identified in several areas of the world , e.g., Yangjian in china , Rsmer in Iran , Kerala coast of India , Istanbul in Turkey ,etc.(Zhu et al.,1993 , Sohrabi,1993,Karahan and Bayulken,2000).

Therefore, measurements of natural radioactivity in soil are of a great interest from many researchers throughout the world, which led to the worldwide national surveys in the last two decades (McAulay and Moran,

1998, Ahmed et al., 1997, Karhan and Bayulken2000; Gur et al 2000; Aljundi, 2002).

This study complements a few other studies, which was conducted in the soil of Karima city in northern Sudan.

1.2 Problem of the Study:

Sudan need a new natural radiologic readings to be a documented 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.

1.3 Objectives:

1.3.1General Objectives:

The main objective of this study is to measure the concentrations of the radioactive elements in soil, in Karima city in northern Sudan.

1.3.2 Specific Objectives:

- To determine the types of natural radioactive elements in soil.
- To measure concentrations of radioactive elements in soil.
- To make a radiological map for Karima 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.

1.4 Thesis Layout:

This thesis consists of five chapters, chapter one is an introduction and consists of problem of the study and objectives.Chapter two is literature review and previous studies.Chapter three consists of materials and methods.Chapter four shows the results of the study.Chapter five involves discussion of the results and recommendations.

Chapter Two

Literature Review

2.1 The Discovery of Radioactivity:

At the time that Thomson was conducting his experiments with cathode rays, other scientists were gathering evidence that the atom could be subdivided. Some of this new evidence show that certain atoms disintegrated by themselves (Frederick E, Trinklein. 1990)

In 1896 Henri Becquerel (1852-1908) discovered this phenomenon while investigating the properties of fluorescent minerals. Fluorescent minerals glow after they have been exposed to strong light. Becquerel used photographic plates to record this fluorescence.

One of the minerals Becquerel worked with was a uranium compound. During a day when it was too cloudy to expose his mineral samples to direct sunlight, Becquerel stored some of the compound in the same drawer with the photographic plates. When he later developed these same plates for use in his experiments, he discovered that they were fogged. What could have produced this fogging? The plates were wrapped tightly before being used, so the fogging could not be due to stray light. Also, only the plates that were in the drawer with the uranium compound were fogged. Becquerel reasoned that the uranium compound must give off a type of radiation that could penetrate heavy paper and affect photographic film (Frederick E, Trinklein1990).

Elements that emit such radiation are called radioactive, and possess the property of radioactivity.

2.2 Radioactivity: is the spontaneous breakdown of an unstable atomic nucleus with the emission of particles and rays.

At the suggestion of Becquerel, Pierre (1859-1906) and Marie curie (1867-1934) investigated uranium and its various ores. They found that all uranium ores were radioactive .However, one of them, pitchblende,

was four times as radioactive as might be expected from the amount of uranium in it. Further studies showed that this extra radiation was actually due to the presence of two previously unknown element, polonium and radium, both of which were intensely radioactive. The elements polonium and radium were discovered and named by the curies.

Other radioactive elements have since been discovered or produced. All of the naturally occurring elements with atomic numbers greater than 83 are radioactive. Also, a few naturally radioactive isotopes of elements with atomic numbers smaller than 83 are known. Many artificial radioactive nuclides have been produced and put to use in different ways (Frederick E, Trinklein 1990).

2.3 Nature of Radioactivity:

All radioactive nuclides have certain common characteristics.

2.3.1 Their radiation affects the emulsion on a photographic film.

Even though the photographic film is wrapped in heavy black paper and kept in the dark, some of the radiations from radioactive nuclides penetrate the wrapping and affect the film. When the film is developed, a black spot can be seen where the invisible radiations struck the film. Some of the radiations penetrate wood, flesh, thin sheets of metal and thick sheet of glass.

2.3.2Their radiations ionize the surrounding air molecules.

The radiations from radioactive nuclides knock out electrons from the atoms of the gas molecules in the air surrounding the radioactive material. This process leaves the gas molecules with positive charge. An atom or a group of atoms having an electric charge called an ion. The production of ions is termed ionization.

2.3.3Their radiations make certain compounds fluoresce.

Radiations from radioactive nuclides produce bright flashes of light when they strike certain compounds. The combined effect of these flashes is a fluorescence, or glow, given off by the affected material. For example radium compounds added to zinc sulfide cause the zinc sulfide to glow.

2.3.4Their radiations have special physiological effects.

Radiations from natural sources can destroy the germinating power of plant seeds, kill bacteria, and even injure and kill large animals. Burns from radioactive materials heal with great difficulty and may sometimes be fatal.

2.3.5They undergo radioactive decay.

The atoms of all radioactive elements continually decay into simpler atoms and simultaneously emit radiations. However, it is not possible to predict when a specific atom will decay. The rate of decay may be described by a rule that states how long it will take for half of the atoms in a given sample to decay. The accuracy of the rule is greater for larger samples. The time associated with radioactive decays of a certain types is called the half-life of the nuclide. Half-life is the length of the time during which, on the average, half of a given number of atoms of a radioactive nuclide decays.

For example, the half-life of radium-226 is 1620 years. This means that one-half of a given sample of radium-226 atoms can be expected to decay into simpler atoms in 1260 years (Frederick E, Trinklein 1990).

2.4 Types of Radioactivity:

Experiments show that the radiations from radioactive materials can be separated into three distinct types:

2.4.1 α (Alpha) Particles:

these are composed of two protons and two neutrons; hence they are helium nuclei. This conclusion can be proved by collecting large quantities of alpha particles in a partially evacuated tube and passing an electric discharge through the tube. The alpha particles acquire electrons from residual air molecules in the tube.Alpha particleshave two positive electric charges, speeds about one-tenth the speed of light, and masses about four times that of the hydrogen atom. Their penetrating power is not very great, they can be stopped by a thin piece of aluminum foil or by a thin sheet of paper.

2.4.2 β (Beta) Particles:

These are electrons, just like cathode rays. They have single negative charges and may travel with nearly speed of light. Their mass is only a small fraction of the mass of alpha particles. Beta particles are much more penetrating than alpha particles. The reason is that beta particles have less charge than alpha particles, and therefore they will lose less energy in passing through a substance.

2.4.3 γ(Gamma)Rays: These are high-energy photons. They are the same kind of radiation as visible light, but of much shorter wavelength and thus higher frequency. Gamma rays are produced by energy transitions in the nucleus that do not change the composition of the nuclide. They are the most penetrating radiations given off by radioactive elements. They are not electrically charged and are not deflected by a magnetic field (Frederick E, Trinklein 1990).

2.5 Sources of Radiation:

Radiation is part of nature. All living creatures from the beginning of time have been and are still being exposed to radiation.

The radiation to which human population is exposed comes from many diverse sources. Some of these sources are natural; others are the result of human activities(HPS).

Sources of radiation can be divided into two categories:

2.5.1Natural Background Sources:

Natural background radiation comes from three sources:

2.5.1.1 Cosmic Radiation:

The earth, and all living things on it, is constantly bombarded by radiation from outer space, similar to a steady drizzle of rain.

Charged particles from the sun and stars interact with the earth's atmosphere and magnetic field to produce a shower of radiation.

The amount of cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

2.5.1.2Terrestrial Radiation:

Radioactive material is also found throughout nature in soil, water, and vegetation.

Important radioactive elements include uranium and thorium and their radioactive decay products which have been present since the earth was formed billions of years ago. Some radioactive material is ingested with food and water. Radon gas, a radioactive decay product of uranium is inhaled.

The amount of terrestrial radiation varies in different parts of the world due to different concentrations of uranium and thorium in soil.

The major isotopes of concern for terrestrial radiation are uranium and the decay products of uranium, such as thorium, radium and radon.

2.5.1.3 Internal Radiation:

People are exposed to radiation from radioactive material inside their bodies. Besides radon, the most important internal radioactive element is naturally occurring potassium-40 but uranium and thorium are also present. The amount of radiation from potassium-40 does not vary much from one person to another. However, exposure from radon varies significantly from place to place depending on the amount of uranium in the soil.

On average, in the United States radon contributes 55% or all radiation exposure from natural and man-made sources. Another 11% comes from the other radioactive materials inside the body.

2.5.2 Man-Made Radiation Sources:

More recently, humans and other organisms have also been exposed to artificial sources developed over the past century o so. Over 80% of our exposure comes from natural sources and only 20% is human made from artificial sources- mainly from radiation applications used in medicine.

The Nuclear Regulatory Commission and other federal and state agencies regulate exposure from man-made radiation sources. Different regulations apply to two distinct groups:

- Members of the public
- Occupational workers.

2.6 Radioactive Decay:

Atoms of all naturally occurring elements with atomic number greater than 83 are unstable and decay spontaneously into lighter particles. This is also true of several naturally occurring nuclides and a great many artificially made nuclides with atomic number below 83. As a general rule, an atomic nucleus is stable if the ratio of its neutrons to its protons is about 1 for the light elements and about 1.5 for the heavier elements. When there are more neutrons than this, a nuclear transformation will probably take place (Frederick E, Trinklein 1990).

Figure(2-1) shows a series of nuclear transformation beginning with uranium -238 and ending with lead-216.

Each step of the series can be represented by a nuclear equation in which nucleons and charge are conserved. For instance the equation for the first step in the chart may be written as:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

This reaction is called alpha decay, because an alpha particle is emitted.The next two steps in the series are examples of beta decay. In the first step, a neutron in the thorium nucleus ejects a beta particle and becomes a proton. This transformation increases the nuclear charge by one, and the nucleus becomes a protactinium nucleus.

$$^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$$

The chart also shows that half-life of each nuclide in the decay series. There is a great variation in these values, from small fraction of a second to millions of years. In each case the exact half-life is related to the energy change that companies the transformation. As a rule, the shorter the half-life of the nuclide, the greater is kinetic energy of the alpha or beta particle it emits.

One radioactive disintegration per second is called a Becquerel (Bq). A sample of radioactive material that emits 3.7×10^{10}Bq is said to have strength of one curie (Ci). Since the curie is a very large unit, the millicurie (mCi) and microcurie (μCi) are frequently used.

The Gray (Gy) is the unit used to measure the absorbed radiation (Frederick E, Trinklein-1990).

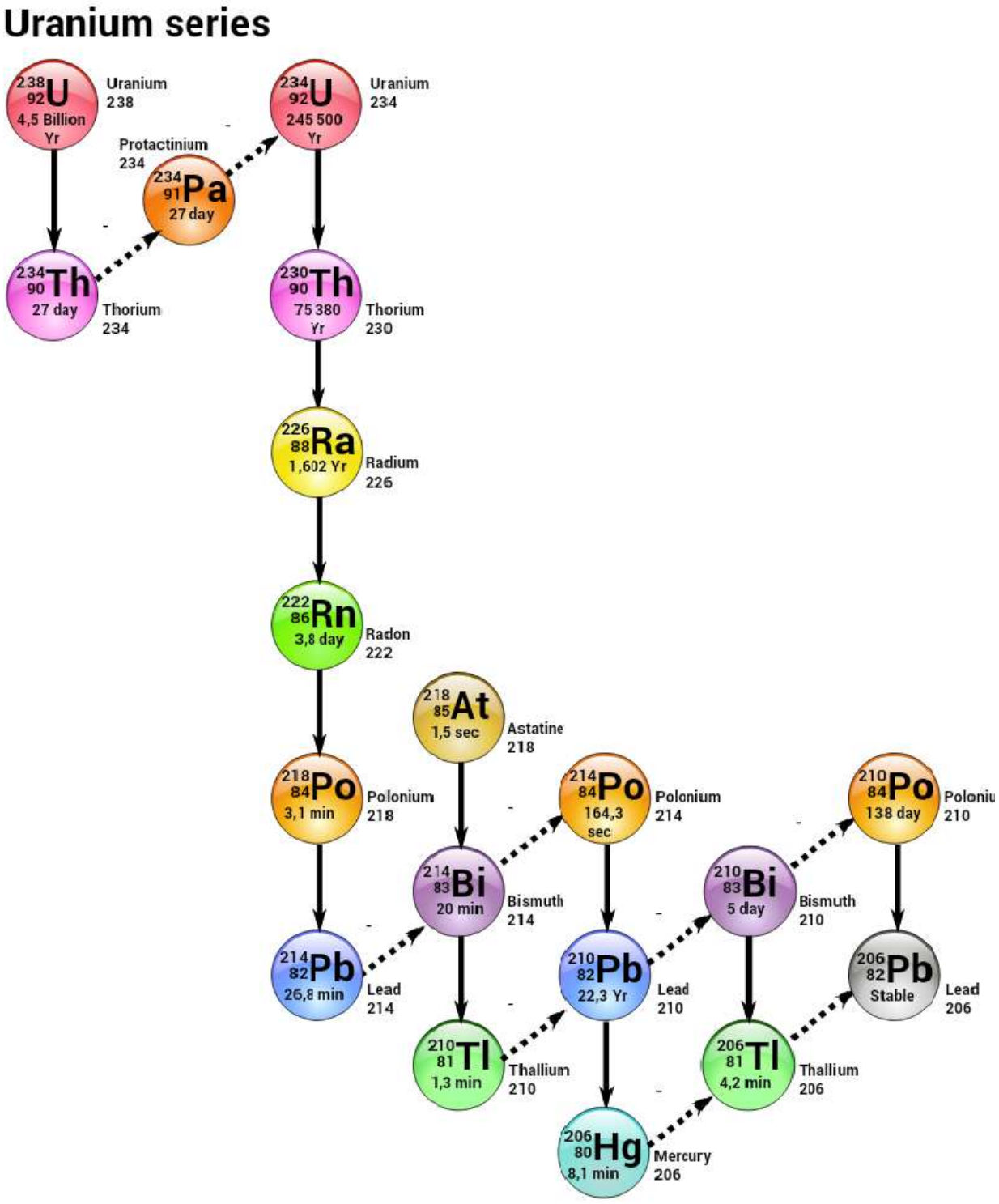


Figure (2-1) : uranium series ↓ α-decay ↗ β-decay

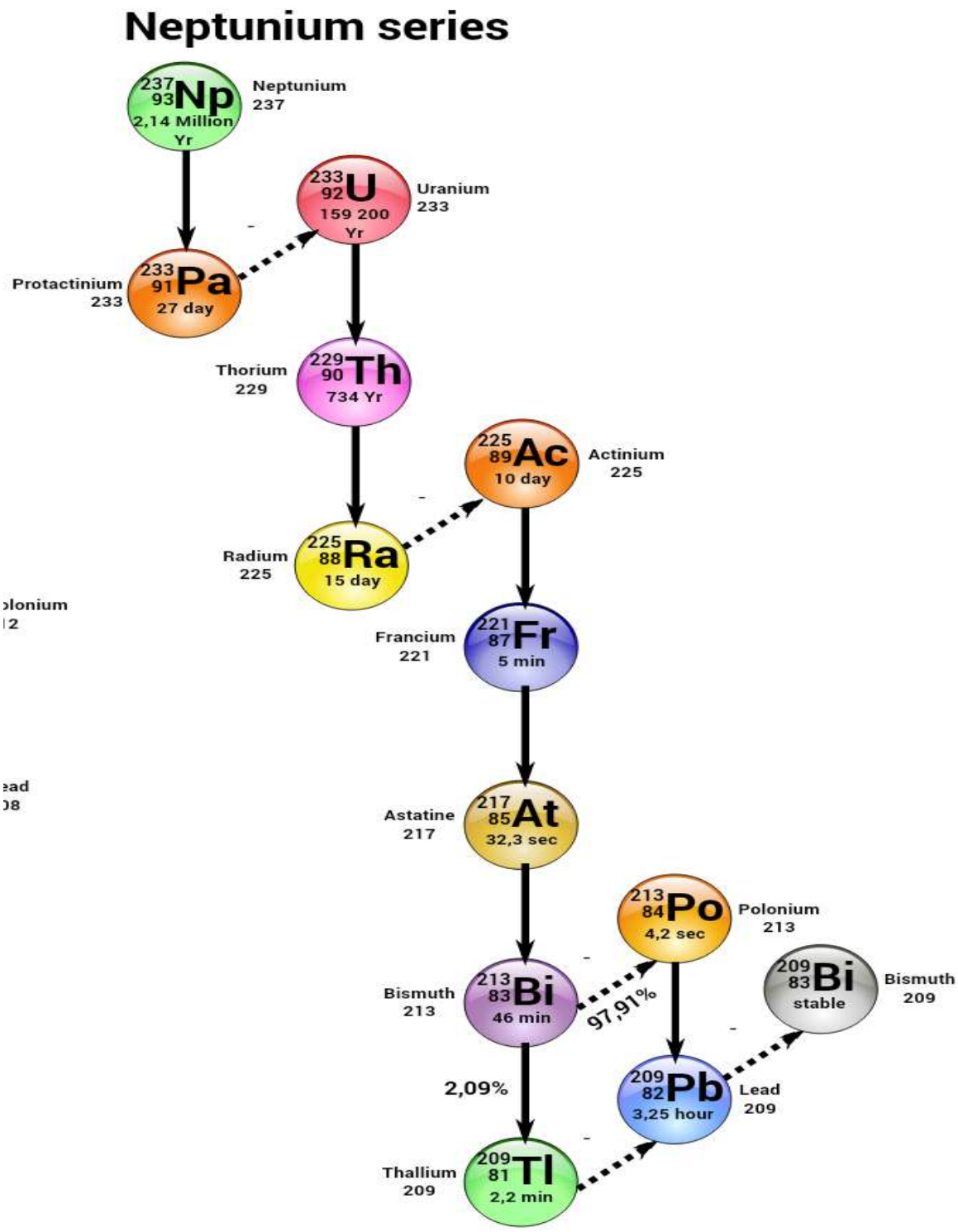


Figure (2-2) : neptunium series α-decay β-decay

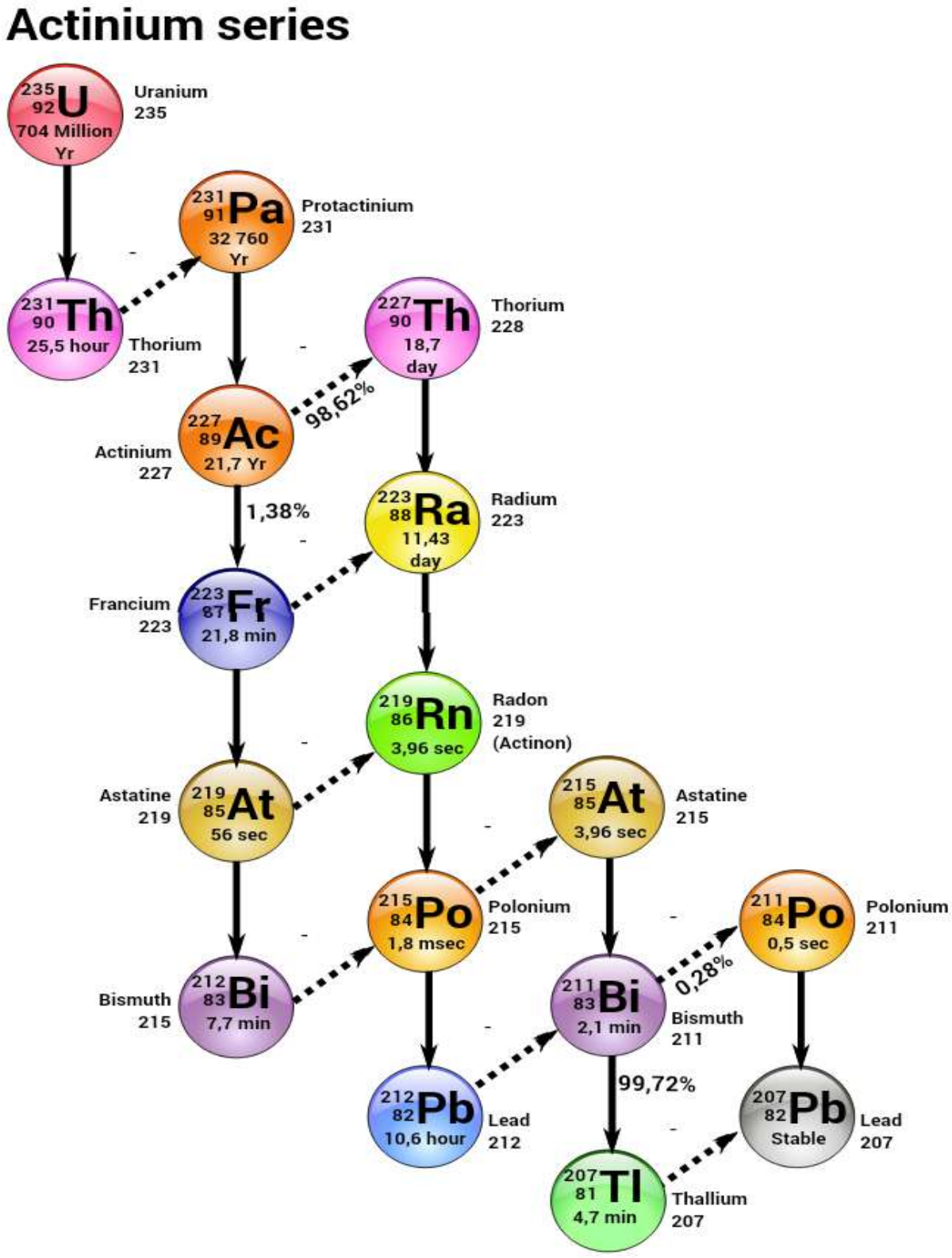


Figure (2-3) : actinium series ↓ α-decay ↗ β-decay

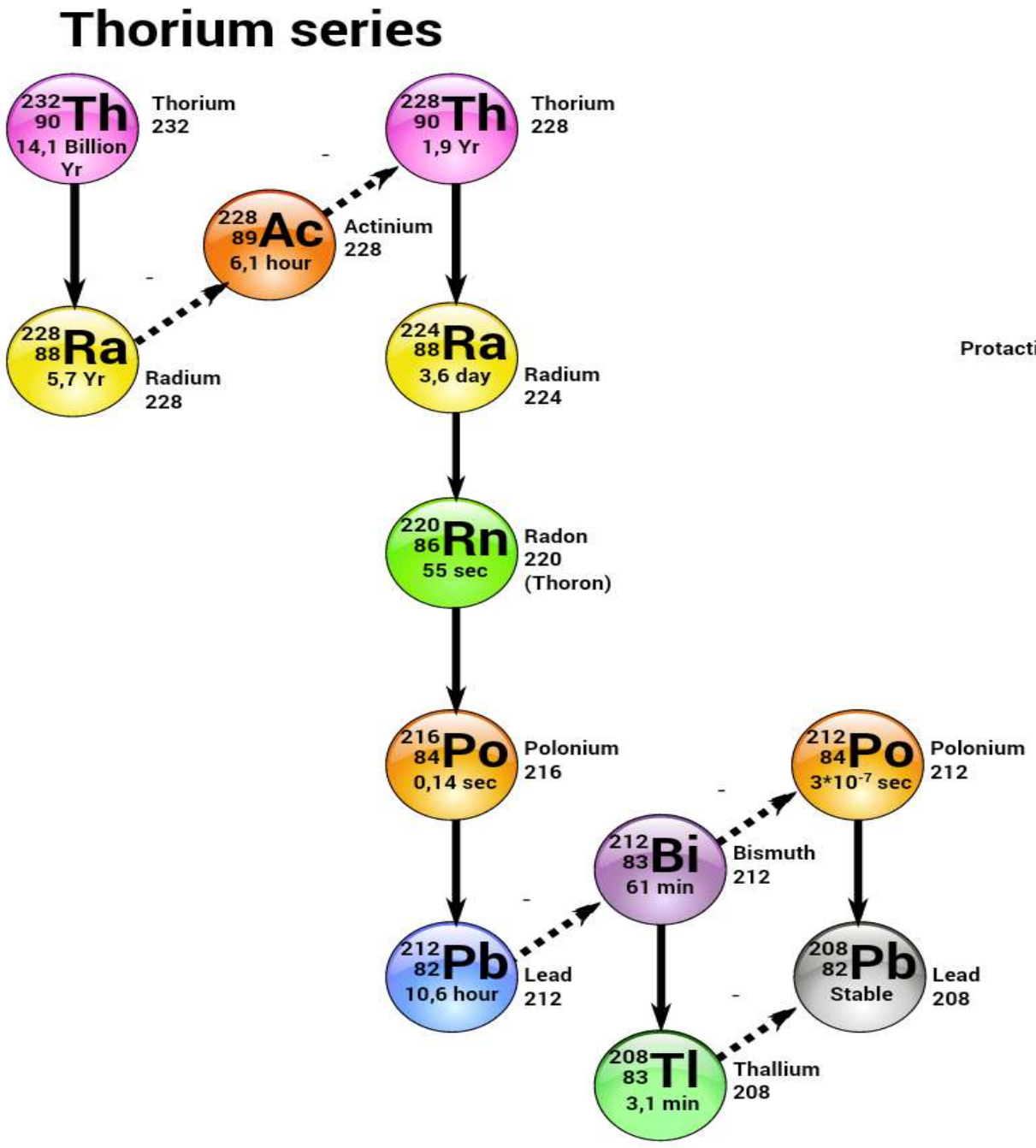


Figure (2-4) : thorium series ↓α-decay ↗β-decay

2.7 Interaction of radiation with matter:

Radiation as a form of energy can be converted to other forms of energies under favorable 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).

Energy is deposited on atoms and molecules; thus, any effect produced will be initially at atomic level.

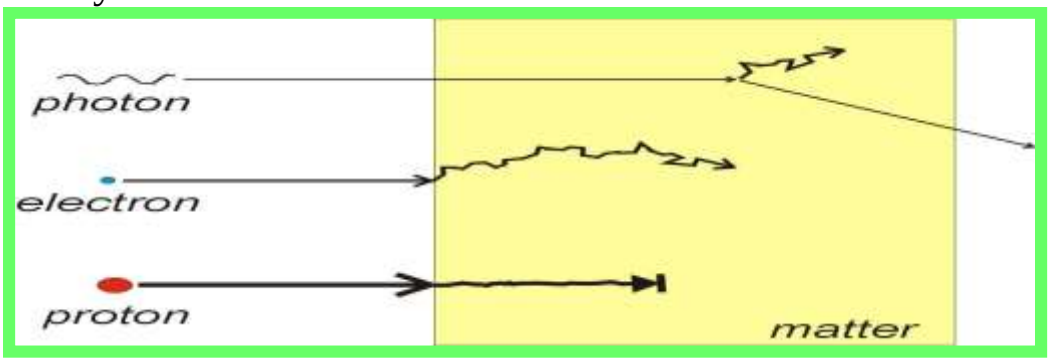


Fig 2.5ranges of different radiations in matter

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, Fig 2.5

2.7.1 Electromagnetic Radiation:

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.

2.7.1.1 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

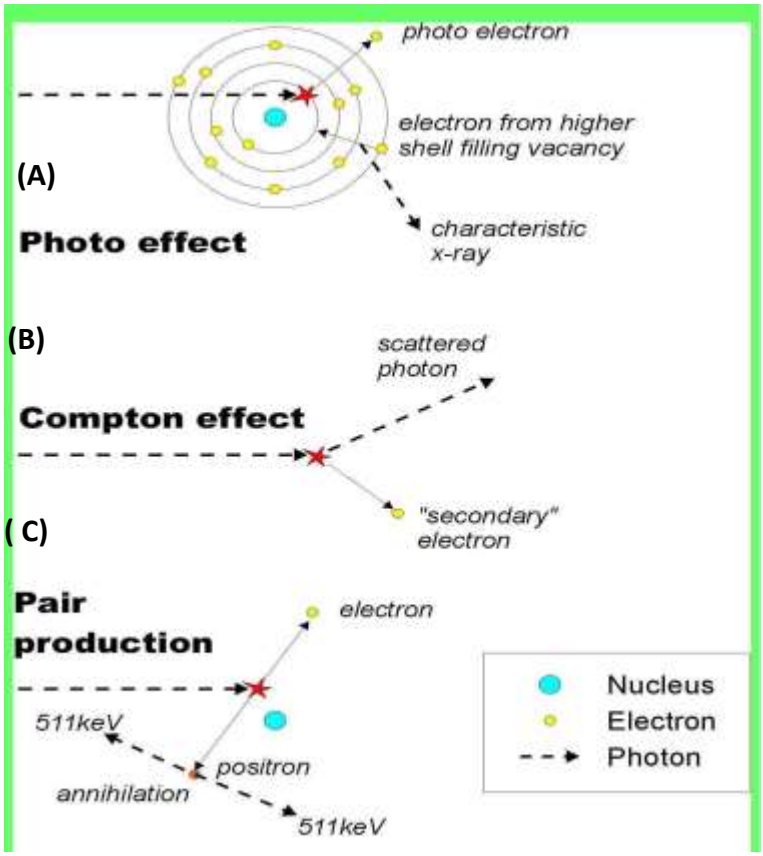


Fig. 2.6 Summery of the Three Modes of Photon Interactions

emitting the energy difference between the two orbits in the form of a characteristic X-radiation Fig 2.6 (A).

In the photoelectric effect, the incoming photon, with energy hν, disappears completely and an electron of energy E is emitted from the atom such that:

$$E = h \nu - EB \qquad (2\text{-}1)$$

where EB is the binding energy of the freed electron called the photo-electron. This electron will either be absorbed in the material or if it has enough energy escape from the absorber.

The photoelectric effect is a process which is dominant in low photon energies; the effect depends strongly on the atomic number of the target

material, through this process photons may be removed from the beam resulting in reduction of beam intensity. This probability of occurrence of photoelectric interaction is known as the photoelectric attenuation coefficient of the beam.

2.7.1.2 The Compton Scattering:

If the photon has higher energy hν1, 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:

$$h\nu_1 = h\,\nu_2 + E_k \qquad (2\text{-}2)$$

the frequency of the incident photon ν_1 is greater than that of the scattered photonν_2, this process is known as Compton scattering Fig 2.6 (B); 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.

2.7.1.3 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 Fig 2.6 (C). 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.

$$h\,\nu \beta^{+} + \beta^{-} \qquad (2\text{-}3)$$

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.

The three modes of interaction depend on energy of the radiation and the atomic number of the medium, except for hydrogen atomic mass of the atom is approximately equal to twice the atomic number A=2Z.

2.7.1.4Attenuation of Electromagnetic Radiation in Matter:

Photons are attenuated exponentially in matter, by interaction with electrons by one of the above mentioned three modes; these interactions result in secondary electrons, which then deposit energy in matter; hence they are called indirectly ionizing radiations.

2.7.2 Interactions of Charged Particles:

Electrons and protons interact with electrons in matter, with usually small transfer of energy, therefore "continuous slowing down". After all energy has been transferred to matter the particle is locally absorbed, leading to a finite range for the particle.

2.7.2.1 Electron interaction in matter

The movement of electrons through matter depends on interactions between electrons and atoms, which may result in energy loss by the electron and/or scattering of the electron. The deposition of energy is usually because of many small interactions between electrons and the irradiated matter. Thus, individual energy depositions are small and a megavoltage electron may deposit energy at >10,000 locations

Energy losses from an electron beam can be divided into two different processes: collision losses and radiative losses. Collisional losses involve interactions with atomic electrons and radiative losses result from interactions with the nuclei of the atom. The energy transferred is directly

related to the absorbed dose in the medium leading to ionization events and excitations of atoms all along the electron path in matter.

The net effect is that each electron interaction leads to production of one or more lower energy electrons and in some cases a photon is emitted.

2.7.2.1.1 Excitation of atoms:

Excitation of the atom occurs when the electron passes some distance from the atom. A small amount of energy (usually a few eV) transfers from the passing electron, to excite an inner atomic electron to an outer shell. When the atomic electron returns to its ground state shell, the excess energy turns into either light or heat, fig 2.7. The primary electron continues with reduced energy and change in its direction.

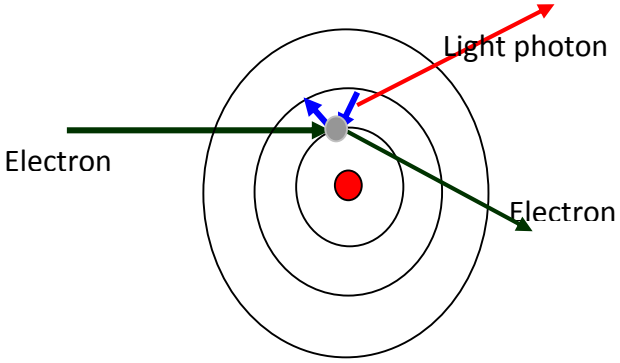
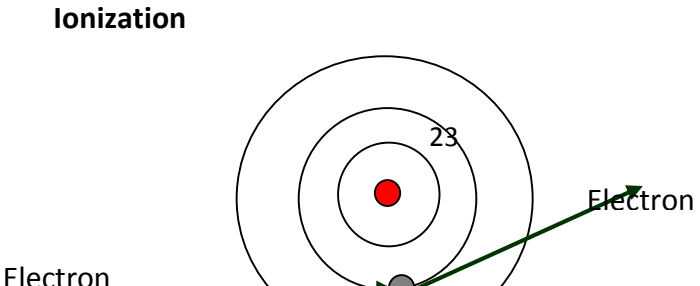


Fig 2.7 Collision losses: excitation

2.7.2.1.2 Ionization

Ionization occurs when the passing electron travels close enough to the atom to interact with a single bound, outer shell electron and to overcome its binding energy. This electron is ejected from the atom, and is known as a secondary electron. Secondary electrons have a much lower energy than the primary electron and do not travel far before coming to rest. The primary electron continues with reduced energy and a change in its direction



2.7.2.1.3Radiative energy losses:

Radiative energy losses occur when a collision between an electron and an atom results in the conversion to radiation of energy lost by the electron.

When the electron passes close to the atom, it is affected by the nuclear coulomb field and changes trajectory with a loss in energy (Fig 2.9). This energy is emitted as a photon with energy hν, known as bremsstrahlung.

Bremsstrahlung production is more efficient for higher energies and higher atomic number media. In practice, the bremsstrahlung content of low energy beams (<10MeV) in water is typically less than 3%. For energies above 40 MeV, the bremsstrahlung content may be 10% or higher.

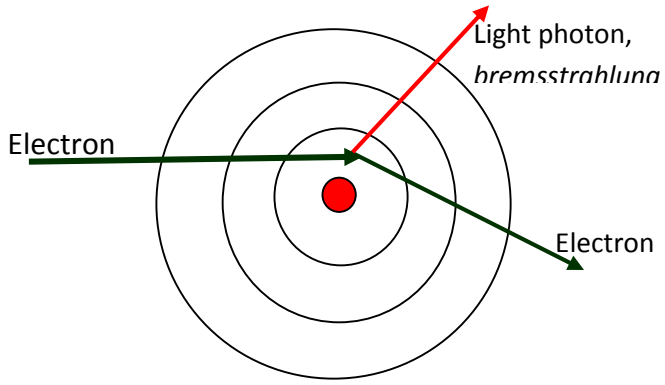


Fig 2.9 Radioactive energy losses: Bremsstrahlung production

2.7.2.1.4
Characteristic radiation

More rarely, interaction with passing electron can cause an electron to be emitted from an inner shell, so that characteristic radiation is emitted as an outer shell electron takes its place. (Fig 2.10.)

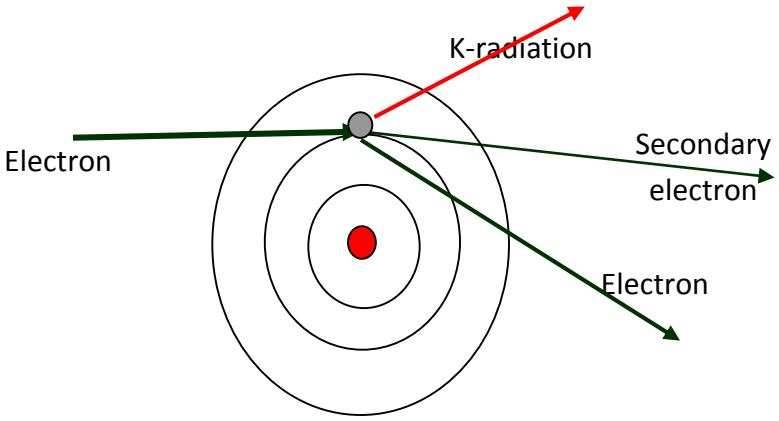


Fig 2.10 Radioactive energy losses production of characteristic radiation

2.8 Radiation Detection

2.8.1 Principles of Radiation Detection

Radiation cannot be sensed but being a form of energy, it can be converted into other forms of energies that can be measured and quantified e.g. heat, electric, light, chemical. As such it is quantified by measuring some quantifiable effects. Many other physical quantities are measured by the size of effect they produce, so temperature is measured by measuring the expansion of gases, liquids or solid produced when they are heated (Prof. Nadia Omer, series of lectures).

A number of other dosimetric techniques are employed to quantify ionizing radiation; all dosimetric techniques have their respective advantages and disadvantages. Table 1 highlights the commonly used dosimetric techniques, of these ionisation chambers, semiconductors, thermoluminescencedosimetry and radiographic film are the ones which are normally used in medicine (Prof. Nadia Omer, series of lectures).

Table 2-1: Effects of ionizing radiation and their use in dosimetry

Radiation effect	Dosimetric method
Ionization in gases	▪ Ionization chamber
Ionization in liquids	▪ Liquid filled ionization chamber
Ionization in solids	▪ Semiconductors ▪ Diamond detectors
Luminescence	▪ Thermoluminescencedosimetry
Fluorescence	▪ Scintillators
Chemical transitions	▪ Radiographic film ▪ Chemical dosimetry ▪ NMR dosimetry
Heat	▪ Calorimetry
Biological effects	▪ Erythema ▪ Chromosome damage

Not all these techniques are used in all radiotherapy departments on routine basis. Each of them has specific advantages and demonstrate certain features of dosimetry, in general, which makes it worthwhile to know about them .

2.8.2 TypesOfDetectors:

Detectors may be classified by the type of information produced:

- Detectors, such as Geiger-Mueller (GM) detectors, that indicate the number of interactions occurring in the detector are called ***counters.***
- Detectors that yield information about the energy distribution of the incident radiation, such as NaI scintillation detectors, are called ***spectrometers.***
- Detectors that indicate the net amount of energy deposited in the detector by multiple interactions are called ***dosimeters*** (Prof. Nadia Omer, series of lectures)**.**

2.8.2.1Counters:

•Gas filled detectors •Scintillation detectors

2.8.2.2 Spectrometers:

•Scintillation detectors •Solid state detectors

2.8.2.3 Dosimeters:

•Gas filled detectors •Solid state detectors

•Scintillation detectors •Thermoluminescentdetectors •Film

2.8.3Instruments for Detecting and Measuring Radiation:

2.8.3.1Survey Meters:

- ❖ Geiger-Mueller (GM) instruments
- ❖ Ionization chamber instruments
- ❖ Scintilation instruments

2.8.3.2Laboratory Counters:

- ❖ Dose calibrator

2.8.3.3Personnel Dosimeters:

- ❖ Photographic film dosimeters
- ❖ Thermoluminescent dosimeters
- ❖ Pocket dosimeters

2.9Previous Studies:

2.9.1 Moawia Mohammed Elmahdi and Adam Khatir Sam, assessed the terrestrial gamma radiation in sinnarstate,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).

2.9.2 AdilAljezoly Mohammed Ali and Nadia Omer Al-Atta measured the natural radioactive elements concentration in Wadihalfa**.** 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.

2.9.3 Canakkale measured natural radioactivity- and concentrations in soil samples taken along the Izmir-Ankara E-023 highway. He was found that The soil activity ranged from 42.6 to 47.3 Bq/Kg for ^{238}U, 31.8 to 36.3 Bq/Kg for ^{232}Th, and 432 to 488 Bq/Kg for ^{40}K. the highest mean value of ^{238}U was found in the oil samples obtained from a sit close to the intersection of the roads and Alasehir. The study yielded an annual effective dose equivalent in the range of 58-80 μSv. The average value falls within the global rang of outdoor radiation exposure given in UNSCEAR -2000 publications. Also K, Ca, Ti, Fe, Cu, Zn, Rb, Sr and Zr concentrations were determined in roadside soil. Zn, Rb, Sr and Zr concentrations in roadside soil around the intersection of the roads and Ala□ehir were higher than maximum concentration level of these heavy metals in normal soil.

2.9.4 Ibrahim, Akpa,T.C.,andDaniel,I,H. assessed the radioactivity concentration in soil of some mining areas in central nasarawa state, Nigeria

They were found that the mean natural activity concentration were 403.963±7.29Bq/Kg , 32.25±4.65 Bq/Kg and 56.23±2.30Bq/Kg for ^{40}K, ^{226}Ra and ^{232}Th respectively .The results obtained were a bit lower compare to the world average value, except for ^{232}Th which is higher than the world average .

Chapter Three

Materials and Methods

3.1 Area of the Study:

This study was conducted in northern Sudan at karima city, about 400 km from Khartoum on a loop of the Nile. Within coordinates 18°33' 0" N, 31°51' 0" E.

Karima city is an important agricultural area, in addition to Albarkal Mountain and the pyramids surrounding it, are important archaeological sites which they were visited by many tourists.

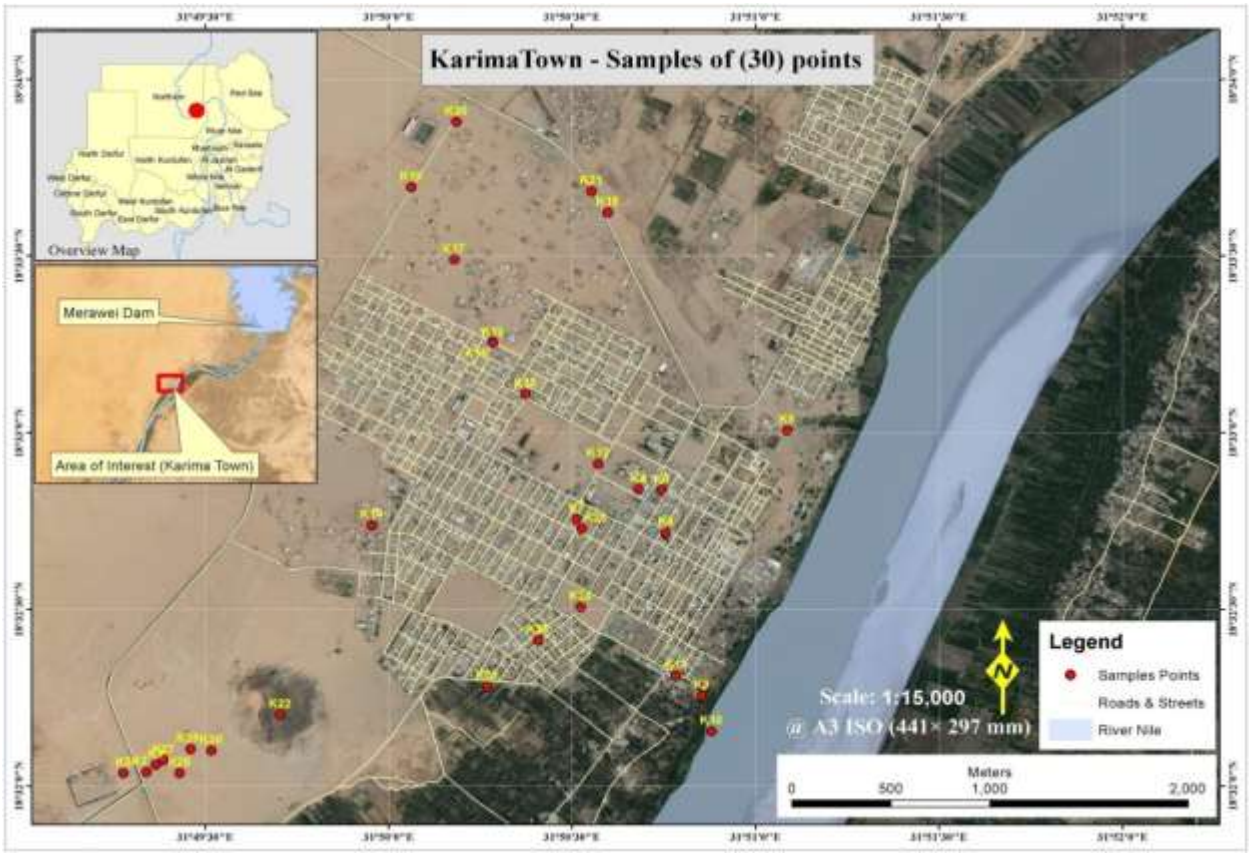


Fig 3.1 Gps Locations Of Samples

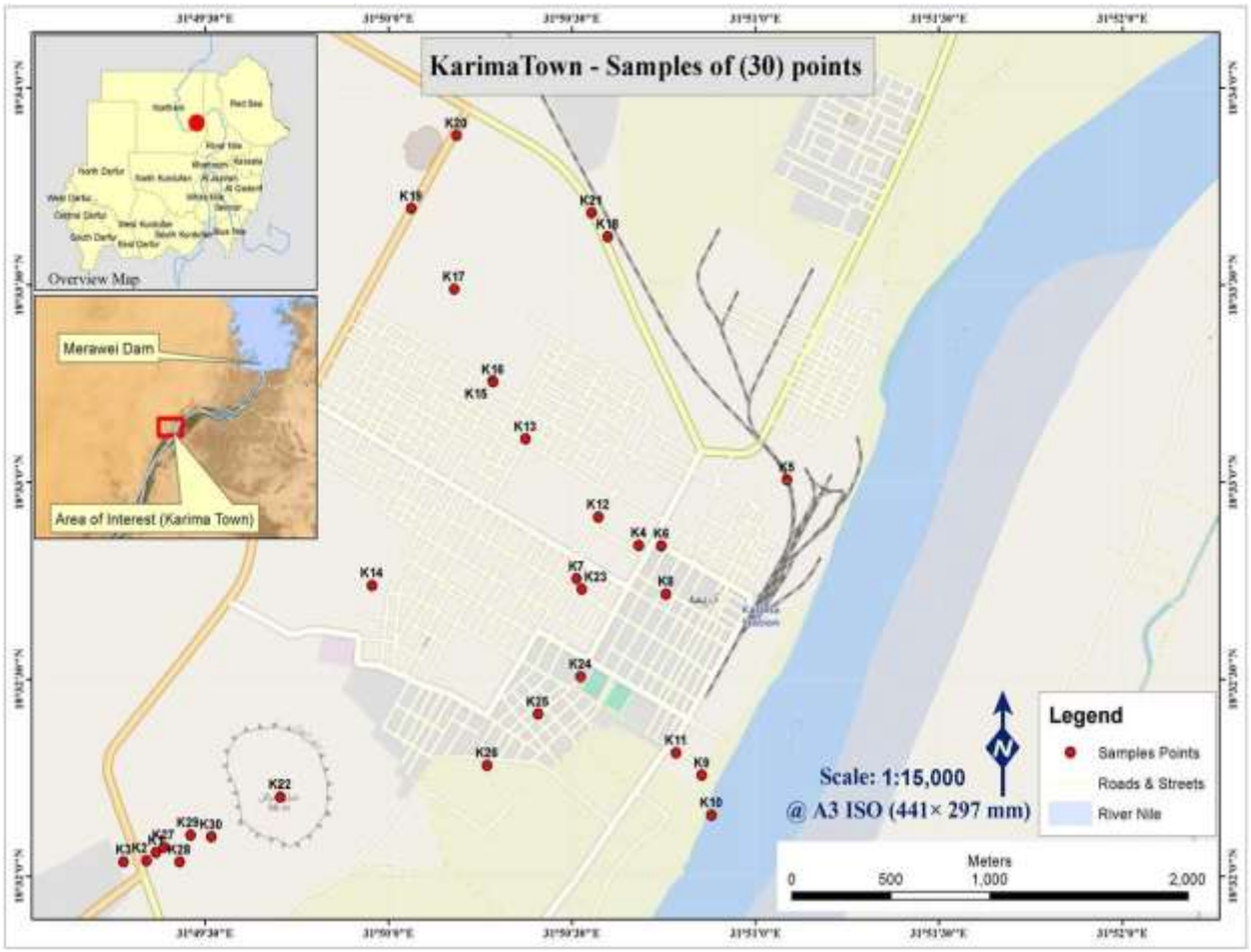


Fig 3.2 Locations Of Samples

3.2Materials:

3.2.1 Samples.

3.2.2 Ruler.

3.2.3 Plastic bags.

3.2.4Weighers.

3.2.5 Digging tool.

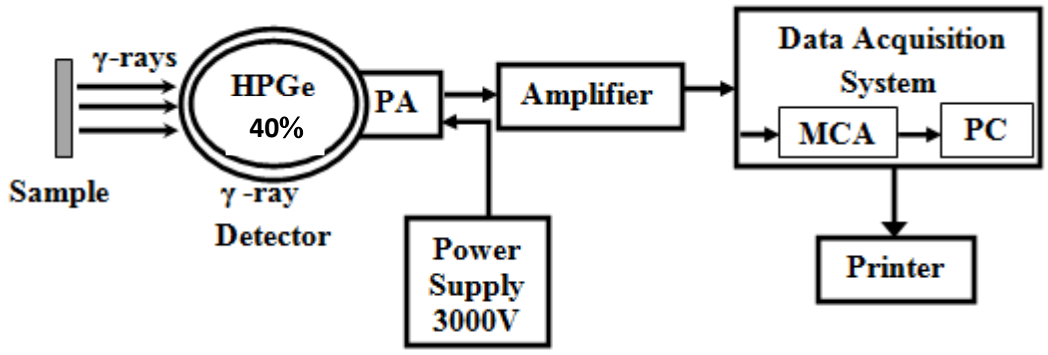
3.2.6 GPS system.

3.2.7 High Purity Germanium Device (HPGe):

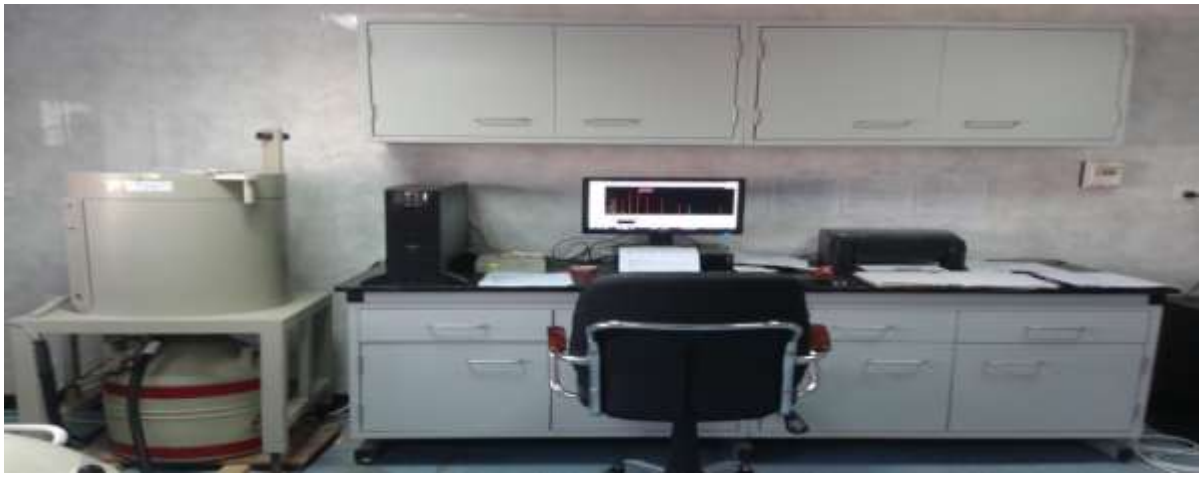
Specific activities of the radionuclides were determined by using the gamma ray spectrometry method using high purity Germanium (HPGe), P-type coaxial detector, GCD30185x model with 37% relative

Efficiency and multi-channel analyzer 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}.



Fig(3-3): high purity germanium system



Fig(3-4): gamma ray spectroscopysystem with high purity Germanium detector (HPGe).

3.3Methods:

3.3.1 SamplesCollection and Preparation:

Thirty soil samples were collected from different points in the area.1 kg of soil samples were collected from each point. Samples were taken at depth of (30 cm), collected in plastic labeled bags and marked by the number k1, k1, k3…etc. after collection of samples, they were brought into the laboratory of the Radiation safety institute, dried, sieved to get rid of gravels, plant roots and grasses.

Then they were crushed into fine powder by using a mortar. 600 g of homogenous soil samples were then packed in containers (500ml Marinelli beakers), and carefully sealed for four weeks in order to maintain radioactive equilibrium of uranium chain.

3.3.2 Determination of Locations:

The positions of samples were determined by GPS system “geographical positioning system”.

3.3.3Absorbed Dose Rates:

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:

$$D = (0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{k}) \quad (3\text{-}1)$$

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

3.3.4 Annual Effective Dose Rates:

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,

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

3.3.5Radium Equivalent Activity:

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 Bq Kg^{-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:

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

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

3.3.6External Hazard Index:

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.andXiolan, Z)

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{k}}{4810} \quad (3\text{-}4)$$

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

3.3.7Representative Gamma Index:

The Representative Gamma index$I_{\gamma r}$ is used to estimate the γ-radiation hazard associated with the natural radionuclide in specific investigated samples. The RepresentativeGammaIndex is also used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials.

Values of $I_{\gamma r}$ were calculated according to the following formula (NEA-OECD.,1979):

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_{k}}{1500} \quad (3\text{-}5)$$

3.3.8 Data analysis:

Data were statistically analyzed by using Microsoft office excel.

Chapter Four

Results

4.1 Introduction:

in this chapter the concentrations of the radioactive radionuclides and the other radioactive contamination indicators were calculated by using the equations mentioned in chapter three.

The results were shown in tables and chart

Table 4-1 : GPS locations of samples

Sample	**Latitude**	**Longitude**
K1	18˚32' 03.6" N	31˚49' 21.9" E
K2	18˚32' 02.4" N	31˚49' 20.4" E
K3	18˚32' 02.2" N	31˚49' 16.6" E
K4	18˚32' 50.4" N	31˚50' 40.9" E
K5	18˚33' 00.4" N	31˚51' 05.1" E
K6	18˚32' 50.3" N	31˚50' 44.6" E
K7	18˚32' 45.3" N	31˚50' 30.7" E
K8	18˚32' 43.0" N	31˚50' 45.3" E
K9	18˚32' 15.4" N	31˚50' 51.2" E
K10	18˚32' 09.3" N	31˚50' 52.8" E
K11	18˚32' 18.8" N	31˚50' 47.0" E
K12	18˚32' 54.7" N	31˚50' 34.3" E
K13	18˚33' 06.6" N	31˚50' 22.4" E
K14	18˚32' 44.3" N	31˚49' 57.3" E
K15	18˚33' 15.4" N	31˚50' 17.0" E
K16	18˚33' 15.3" N	31˚50' 17.1" E
K17	18˚33' 29.4" N	31˚50' 10.7" E
K18	18˚33' 37.4" N	31˚50' 35.8" E
K19	18˚33' 41.7" N	31˚50' 03.7" E
K20	18˚33' 52.8" N	31˚50' 11.1" E
K21	18˚33' 41.0" N	31˚50' 33.2" E
K22	18˚32' 12.1" N	31˚49' 42.3" E
K23	18˚32' 43.7" N	31˚50' 31.6" E
K24	18˚32' 30.4" N	31˚50' 31.4" E
K25	18˚32' 24.7" N	31˚50' 24.4" E
K26	18˚32' 16.9" N	31˚50' 16.1" E
K27	18˚32' 04.4" N	31˚49' 23.2" E
K28	18˚32' 02.2" N	31˚49' 25.8" E
K29	18˚32' 06.3" N	31˚49' 27.6" E
K30	18˚32' 06.0" N	31˚49' 31.0" E

Table4-2: activity concentrations (Bq/Kg) in soil samples:

Sample	Ra-226	Th-232	K-40
K1	12	19	111
K2	15.7	55	80
K3	10.6	22.3	71
K4	7.05	9.7	71
K5	15.3	19.6	145
K6	8.3	14.5	98
K7	11.7	17.4	129
K8	9.3	15.1	160
K9	14.2	18.2	278
K10	11.6	16.5	378
K11	10.2	14.6	106
K12	7.48	10.8	79
K13	12.3	20.7	143
K14	11.7	15.4	159
K15	10.2	16.2	12
K16	14	21.3	99
K17	14	26.1	123
K18	13.1	24.9	122
K19	13	23.5	123
K20	10.7	16.9	126
K21	9.4	14.1	117
K22	13.1	23.6	148
K23	12.2	22.1	153
K24	9.9	18.2	72
K25	10.7	20.6	94
K26	11.4	19.1	195
K27	7.6	12.5	96
K28	19.2	30.7	133
K29	11	26.8	59
K30	10.5	17	108

Max	19.2	30.7	378
Min	7.05	9.7	59
Average	11.581	20.08	130.1
Stdev	2.624	8.160	63.602
Median	11.5	18.6	122.5

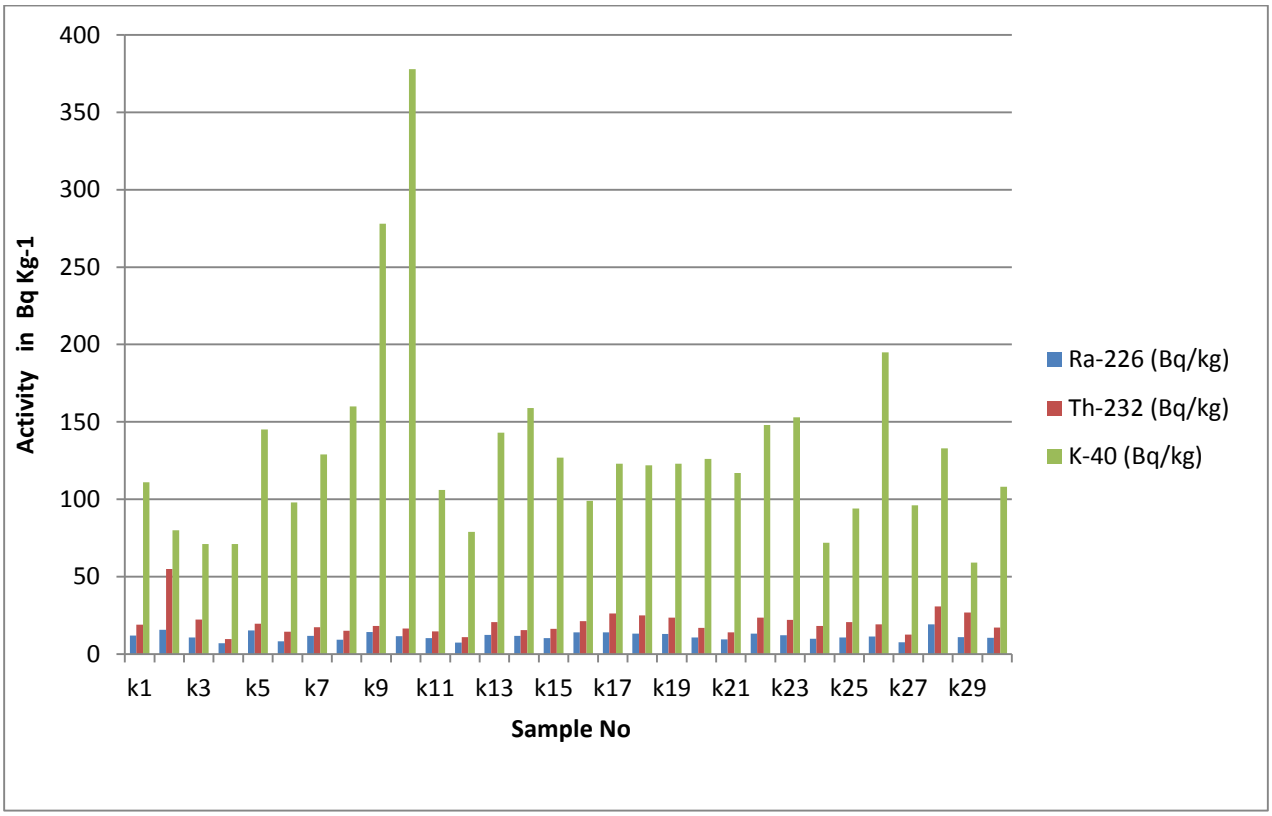


Figure 3-4: Distribution of Ra-226, Th-232 and K-40 in soil samples

Table 4_3: Dose rates ($nGyh^{-1}$)

Sample	**D($nGyh^{-1}$)**
K1	21.6487
K2	43.8094
K3	21.3271
K4	12.0766
K5	24.9535
K6	16.6792
K7	21.2943
K8	20.089
K9	29.1458
K10	31.0878
K11	17.951
K12	13.27326
K13	24.1485
K14	21.3373
K15	19.7931
K16	23.4615
K17	27.3615
K18	26.1792
K19	25.3291
K20	20.4052
K21	17.7381
K22	26.4782
K23	25.3649
K24	18.569
K25	21.3056
K26	24.9347
K27	15.0644
K28	32.9593
K29	23.7295
K30	19.6226

Max	32.95
Min	12.07
Median	21.493
Average	22.903
Stdev	6.260

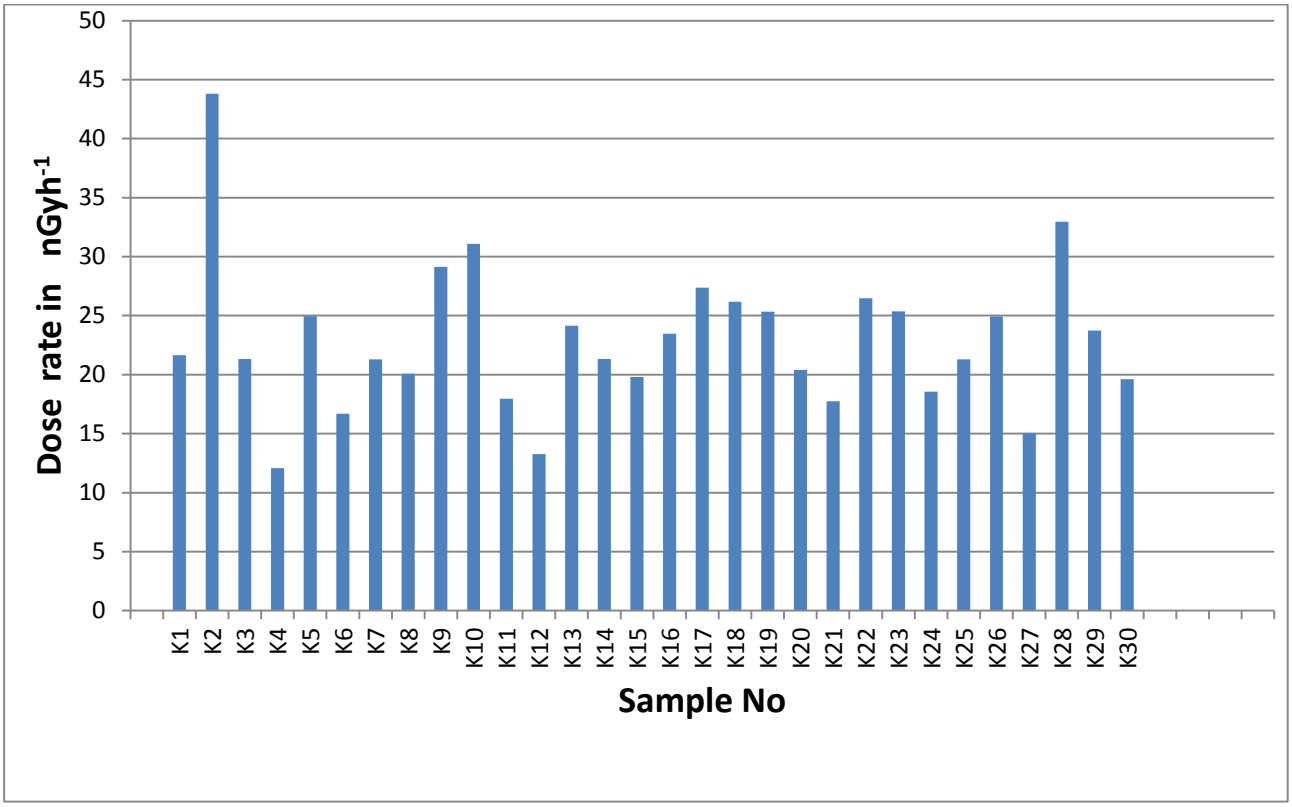


Figure 4-4 : distribution of the dose rate in soil samples

Table 4_4: Annual effective dose equivalent (μSvy^{-1})

Sample	**AEDE (µSvy-1)**
K1	26.54996568
K2	53.72784816
K3	26.15555544
K4	14.81074224
K5	30.6029724
K6	20.45537088
K7	26.11532952
K8	24.6371496
K9	35.74440912
K10	38.12607792
K11	22.0151064
K12	16.27832606
K13	29.6157204
K14	26.16806472
K15	24.27425784
K16	28.7731836
K17	33.5561436
K18	32.10617088
K19	31.06360824
K20	25.02493728
K21	21.75400584
K22	32.47286448
K23	31.10751336
K24	22.7730216
K25	26.12918784
K26	30.57991608
K27	18.47498016
K28	40.42128552
K29	29.1018588
K30	24.06515664

Max	53.727842
Min	714.81074
Average	28.08
Stdev	7.678
Median	26.3590152

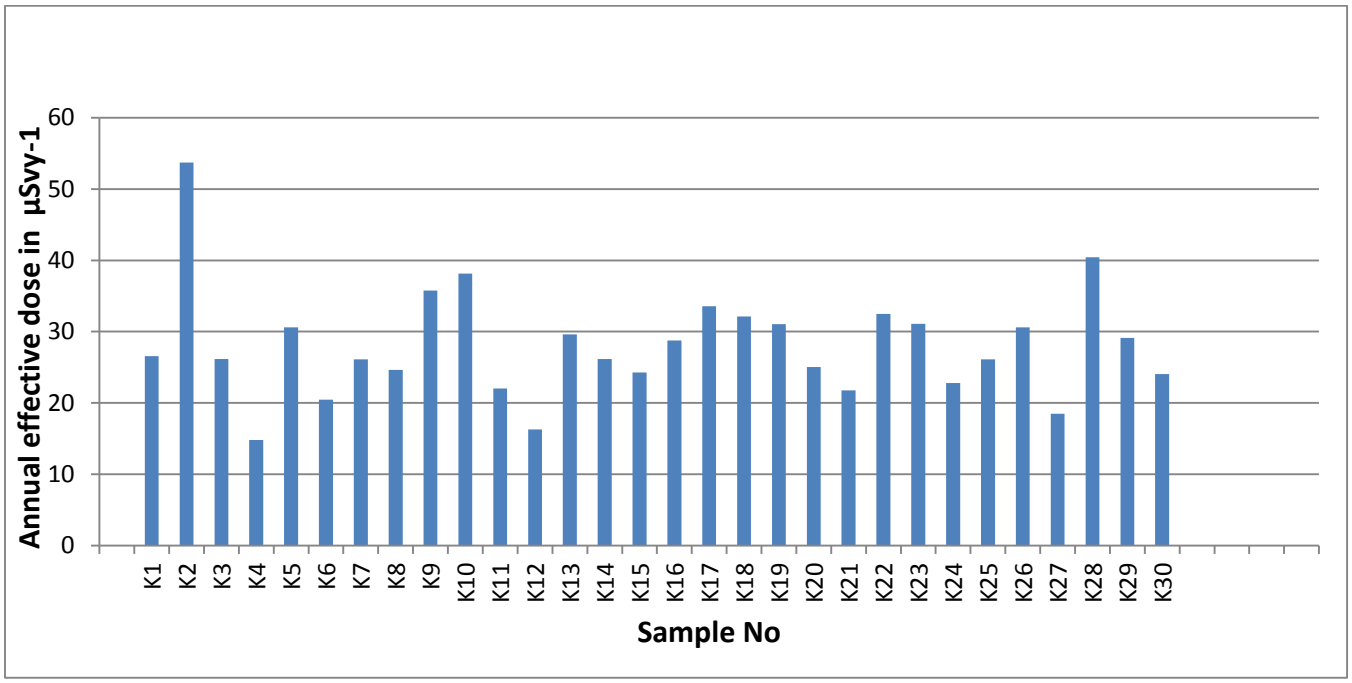


Figure 4-5 : distribution of the annual effective dose in soil samples

Table4_ 5: Radium equivalent activity ($BqKg^{-1}$)

sample	Ra_{eq} ($BqKg^{-1}$)
K1	47.717
K2	100.51
K3	47.956
K4	26.388
K5	54.493
K6	36.581
K7	46.515
K8	43.213
K9	61.632
K10	64.301
K11	39.24
K12	29.007
K13	52.912
K14	45.965
K15	43.145
K16	52.082
K17	60.794
K18	58.101
K19	56.076
K20	44.569
K21	38.572
K22	58.244
K23	55.584
K24	41.47
K25	47.396
K26	53.728
K27	32.867
K28	73.342
K29	53.867
K30	43.126

Max	100.51
Min	26.388
Average	50.3131
Stdev	14.1645
Median	47.8365

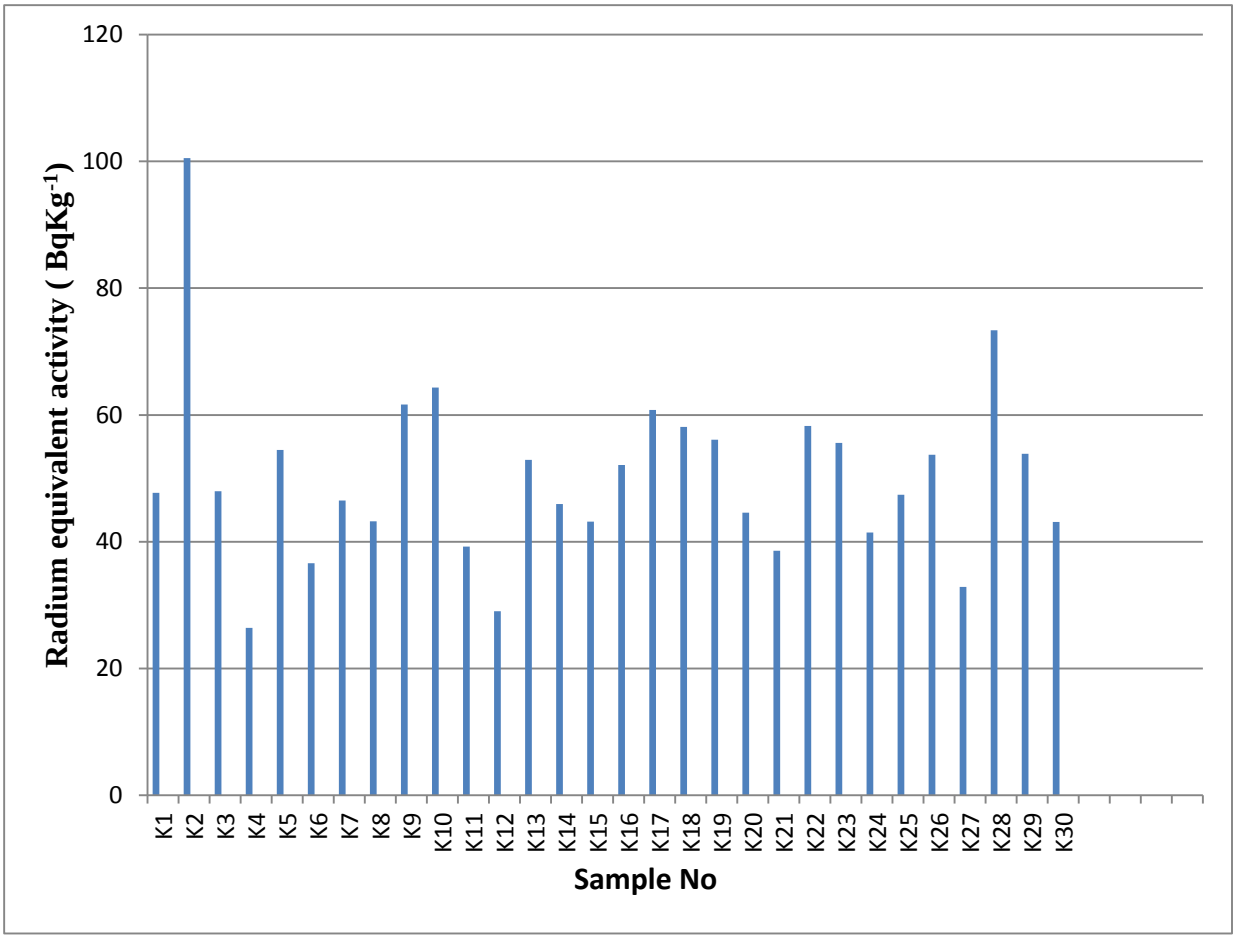


Figure 4-6: distribution of Radium equivalent activity

Table 4_ 6: External hazard index

sample	Hex
K1	**0.128868**
K2	**0.27142**
K3	**0.12951**
K4	**0.071267**
K5	**0.147173**
K6	**0.098791**
K7	**0.125622**
K8	**0.1167**
K9	**0.166445**
K10	**0.173644**
K11	**0.105976**
K12	**0.078339**
K13	**0.142896**
K14	**0.124137**
K15	**0.116519**
K16	**0.140659**
K17	**0.164182**
K18	**0.156908**
K19	**0.15144**
K20	**0.120365**
K21	**0.10417**
K22	**0.157294**
K23	**0.15011**
K24	**0.111996**
K25	**0.127998**
K26	**0.145097**
K27	**0.088762**
K28	**0.198075**
K29	**0.145471**
K30	**0.116469**

Max	0.27142
Min	0.07126
Average	0.135877
Stdev	0.03825
Median	0.3425

Table 4-7: Representative Gamma index

Sample	$I_{\gamma r}$
K1	0.344
K2	0.708
K3	0.341
K4	0.191333
K5	0.394667
K6	0.265667
K7	0.338
K8	0.319667
K9	0.462
K10	0.494333
K11	0.284667
K12	0.210533
K13	0.384333
K14	0.338
K15	0.314667
K16	0.372333
K17	0.436333
K18	0.417667
K19	0.403667
K20	0.324333
K21	0.281667
K22	0.422
K23	0.404333
K24	0.296
K25	0.34
K26	0.397
K27	0.239667
K28	0.523667
K29	0.380667
K30	0.312

Max	0.52366
Min	0.191333
Average	0.36474
S.D	0.100959977
Median	0.129189

Table 4-8: Comparison between the values obtained in this study and other studies

	$\mathbf{A}_{Ra}$ BqKg^{-1}	$\mathbf{A}_{Th}$ BqKg^{-1}	$\mathbf{A}_{k}$ BqKg^{-1}	**D**nGyh^{-1}	**AEDE**µSvy^{-1}	BqKg^{-1}**Ra**$_{eq}$	H_{ex}	$I_{\gamma r}$
Ave	**11.58**	**20.08**	**130.1**	**22.90**	**28.08**	**50.31**	**0.135877**	**0.36474**
Stdv	**2.624**	**8.160**	**63.602**	**6.260**	**7.678**	**14.164**	**0.03825**	**0.100959977**
Max	**19.2**	**55**	**378**	**32.95**	**53.727**	**100.51**	**0.27142**	**0.52366**
Min	**7.05**	**9.7**	**59**	**12.07**	**14.810**	**26.388**	**0.07126**	**0.191333**
Local study (sinnar state)	**17.21±2.41**	**38.01±8.21**	**177.44±19.08**	**38.08±7.02**	**47.59±6.07**	**—**	**—**	**—**
International study(Bangladesh)	**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**	**—**

Chapter Five

Discussion of Results

5.1 Discussion:

The specific activities of ^{226}Ra, ^{232}Th and ^{40}K were measured, and the results were shown in table 2 at the previous chapter.

The activity of ^{226}Ra was found ranged from 7.05 to 19.2 Bq Kg^{-1}, with an average of 11.581 Bq Kg^{-1}. The highest activity was found in sample No k28.

The activity of ^{232}Th was found ranged from 9.7 to 55 Bq Kg^{-1}, with an average of 20.08 Bq Kg^{-1} .the highest activity was found in sample No k2.

The activity of ^{40}K were found ranged from 59 to 378 Bq Kg^{-1}, with an average of 130.1 Bq Kg^{-1} .the highest activity was found in sample No k10.

The calculated dose rate evaluated in table 3 was found in the range of 12.07 - 32.95 $nGyh^{-1}$, with an average of 22.9 $nGyh^{-1}$.

The calculated annual effective dose evaluated in table 4, was found in the range of 14.81- 53.72 μSvy^{-1}, the average value is 28.08μSvy^{-1}.

Radium Equivalent activity was found in the range of 26.38 - 100.51 Bq Kg^{-1}, the average value is 50.31 Bq Kg^{-1}

The results in table 6 revealed the external hazard index which is less than 1 in all locations and can be considered as low since the value is less than one (Krieger, 1981; Beretka& Mathew, 1985).

As illustrated in table 7 the representative gamma index is ranging from 0.191333 to 0.52366 with an average of 0.36474, in all samples, the

calculated values of $I_{\gamma r}$ are less than 1, which can be considered as low.

The results were compared with other studies (sinnar and Bangladesh) and found that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K were the lowest. Also dose rates and the annual effective dose were the lowest.

5.2 Conclusion:

The specific activities obtained from the soil samples which were collected from thirty locations in karima city was found to be the lowest in comparison with other values in previous local study (sinnar), and international study (Bangladesh).

The achieved evaluations of the radiation hazard indices due to concentrations of ^{226}Ra, ^{232}Th and ^{40}K, indicated that the indices were within normal limits, also the radioactivity level index I_{γ} was within normal limits.

5.3 Recommendations:

Future studies should be focused in the northern state and include several regions in the state with different depths. Further studies should be carried out in other samples such as animal bones, plant roots and rocks. Also I recommended finding the concentrations of these elements in other locations in Sudan to complete the radiological map of Sudan.

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