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Assessment of Natural Radioactivity Levels in some Imported Food products in the Iraqi Markets

A Thesis

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By

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ ﴿1﴾ خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ
﴿2﴾ اقْرَأْ وَرَبُّكَ الْأَكْرَمُ ﴿3﴾ الَّذِي عَلَّمَ بِالْقَلَمِ ﴿4﴾
عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ ﴿5﴾

صدق الله العظيم

سورة العلق الآيات **(1-5)**

Dedications

I dedicate this work

To my father and mother, may God have mercy on them

To

my sons and daughters who played a big role in helping me

To

My dear country

Hamza

Acknowledgements

Praise and thanks be to God; who give me ((faith, patience and courage)) to get along completing this work. I would like to express my deep appreciation to my supervisor prof.Dr.Mohanad hussein Oleiwi for suggesting this project, valuable guidance, and encouragement during the development of this project. Without him help, this work would not be possible. My gratitude goes to the dean of College of Education for pure Sciences and the head of the department of physics for their help. I appreciate the cooperation of Dr. Ali Abid Abojassim and Dr. Inaam Hani Kadhim for providing me various researches which benefit in my work. Finally, I am indebted to my family and my friends for their assistant and for providing me invaluable advices

Abstract

The current study included the evaluation of the levels of natural radioactivity of some nuclei in imported foodstuffs, which included 43 samples collected from Iraqi markets,, and the measurements were made using a iodide sodium detector inlaid with thallium NaI(Tl), whose dimensions are (3"×3") to measure the specific activity of uranium ^{238}U, thorium ^{232}Th and potassium ^{40}K nuclei and with a measurement time of four activity hours, and it was found that the average values of specific activity of ^{238}U, ^{232}Th and ^{40}K respectively in rice samples is (16.85±0.52), (20.24±1.08) and (388.87±23.09) Bq/ kg ,while the wheat flour samples were the average values of specific activity (5.56±0.30) (21.41±1.05) ,(120.38±1.38) Bq/kg and finally the legumes samples the values of specific activity were as follows(5.67±0.31), (21.19±0.98), (333.85±4.19) Bq/ kg.

The studied samples were analyzed and compared with the global average and permissible limits set by international scientific agencies (UNSCEAR) and by comparing the results with the universal values ^{238}U=32 ,^{232}Th=45,^{40}K=412 Bq/kg, and according to the Atomic Energy Organization and the International Radiation Protection Committee (ICRP) found that the radioactivity levels of the studied samples in rice, and wheat flour and Legumes and most samples fall within normal permissible ranges and do not pose a radioactive hazard to human consumption.

Also it had been found the average internal hazard index for samples of rice, wheat flour and legumes respectively are (0.419), (0.137) (0.183), and had been found that the average external hazard index for the samples themselves is, (0.212), (0.122) and (0.168) These samples were considered permissible in terms of contamination of nuclear radiation, and is considered normal compared to the limits recommended by the United Nations Scientific Committee for Scientific and Strategic Research (UNSCEAR)

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Symbols	**Description**
A, A_O	Specific Activity
ε	Efficiency
$I\gamma$	Percentages of the intensity of Gamma radiation
λ	Constant radiation decay
α	Alpha Particles
β	Beta Particles
γ	Gamma Ray
$t_{1/2}$	its half life
NaI(Tl)	The Sodium Iodide Detector
H_{in}	Internal Hazard Index
H_{ex}	External Hazard Index
UNSCEAR	United national scientific committee on the effects of atomic radiation
Bq	Becquerel
Ci	Curi
t	Etching time
m	Mass

Chapter One
Introduction and Literature Review

1.1 Introduction

There are many sources of radiation and radiation activity in the environment. The Earth and the atmosphere contain varying levels of naturally radioactive elements such as the Uranium-238 series and the Thorium-232 series, and these radiations are associated with potassium-40 isotope decay. Natural radiation accounts for more than 80% of the total exposure received by humans[1].

There are two primary sources of radiation:

1. High-energy cosmic radiation particles that fall to Earth and the atmosphere and radioactive decay

2. Radionuclides previously found inside the earth's crust are now present in soil, water, and food, as well as in living organisms[2].

Since the formation of the world, radioisotopes have been detected in rocks, soil, and water. Since some of these isotope have extremely long half-lives (millions of years ago or more), huge amounts of these nucleotides are still present on Earth today[3]. Plants absorb radionuclides from the soil[4].

Radionuclide concentrations in food rely on a number of factors. These variables include the kind of food and the region where these chemicals were created, and the most prevalent radioactive particles in nutrients are ^{232}Th, ^{238}U and ^{40}k- is among the most prevalent naturally occurring radioisotopes in foods and is mostly present in milk, as well as in pork, bananas, and other foods. goods high in potassium other naturally occurring radioactive isotopes are present in lesser amounts and are derived from the disintegration of uranium and thorium [5],half -life of ^{40}K is 1.3 billion years, It dissolves by (89%) to ^{40}Ca by the release of beta particles with the accompanying gamma radiation, and by (11%) to ^{40}Ar gas mediated by electronic households with the emission of active gamma rays, ^{40}K can therefore pose internal and external risks. Potassium is an essential component of the body but must be under certain controls as one can find about 2 g of this element per kilogram of body mass which is used to maintain the biological process[6].

Radium 226- in the environment is widely distributed because it is present at different concentrations in water, soil, sediment and rocks. The radioactive importance of radium is highlighted in the fact that it acts chemically such as ^{40}Ca deposited on bone surfaces and mineral metabolic areas. when radium is swallowed, the majority of substances are secreted quickly, however, because the chemical behavior of radium is similar to the chemical behavior of calcium, it is absorbed into the blood through the digestive system (Gastro-Intestinal system) or lungs and follows ^{40}Ca behavior and is deposited primarily in bones[7].

Uranium is found in a variety of food items and the highest concentrations are found in oysters and less has been measured in fresh vegetables, cereals and fish[8].

Uranium appears rapidly in the bloodstream as it is primarily associated with red blood cells.it is exit from the bloodstream is rapid and then accumulates in the kidneys and skeleton while small amounts are found in the liver. The skeleton is the main site of uranium accumulation [9].Humans are also exposed to contaminants from outside their bodies.

Alpha and beta particles are the most prevalent types of ionizing radiation. Radiation can come from a variety of sources, including natural radionuclides as well as man-made ones. High-energy particles from outer space may be continually bombarding the Earth. The cosmic rays react with cores of the atmosphere's components, leading to a chain of events and subsequent metabolic byproducts that result in exposure to cosmic rays that weakens like one falls from aircraft heights to the ground level.

1.2 Previous studies

Numerous investigations and measurements of radioactive element concentrations in foodstuffs have been conducted; some of these research are summarized here.

Hosseini T. *et al*., 2006 studied Twenty six samples of different kinds of imported foodstuff were selected for analysis, all samples were found to contain detectable ^{40}K content in range 6.4 to 778.4 Bq/kg. ^{137}Cs, ^{226}Ra and ^{232}Th were detectable in most of the samples. The maximum concentration of ^{40}K, ^{226}Ra and ^{232}Th were found in tea sample equal to 778.4±23.4, 2.9±0.1 and 5.4±0.2 Bq/kg respectively, whereas for ^{137}Cs it was 3.2±0.1 Bq/kg in milk powder [10].

Zaid Q. *et al*., 2009 studied the activity concentrations of ^{40}K, ^{226}Ra, ^{228}Ra and ^{137}Cs for 14 brands of the powdered milk consumed in Jordan, the activity concentrations of Chapter One General Introduction 4 ^{40}K were found not to vary greatly from one brand to the other with an average of 348+26 Bq/kg. ^{226}Ra and ^{228}Ra were measured above the detection limits in five brands only and displayed relatively low activity concentrations of 0.50–2.14 and 0.78– 1.28 Bq/kg for ^{226}Ra and ^{228}Ra, respectively. The total average annual effective doses due to intake of ^{40}K, ^{226}Ra, ^{228}Ra and ^{137}Cs from the ingestion of the powdered milk for infants, children and adults were estimated to be (in μSv): 332, 138 and 43, respectively. These results indicate no significant radiation dose to the public [11].

Saeed M. *et al*., 2011 researchers analyzed the radioactive content and radioactivity level of several varieties of rice consumed by Malaysians (HYGe).The average concentrations of Uranium, Thorium, and Potassium were (18.33-25.10)0.01 Bq/Kg, (35.49-64.97)0.01 Bq/Kg, and (64.802-109.929)0.001 Bq/Kg, respectively. Effective dosage per year was between 0.02 Sv year-1 and 0.03 Sv per year [12].

Al-Zahrani J. 2012 studied samples of infant's milk used in Saudi Arabia (Jeddah city).The main detected activity corresponding to ^{40}K was 234.18±1.9 Bq/Kg, while the average activities of ^{226}Ra,^{232}Th were 0.46 Bq/kg, and 0.35 Bq/kg. The total average effective dose due to annual intake of ^{226}Ra, ^{232}Th and ^{40}K from the ingestion of the powdered milk for infants were estimated to be 410μSv for infant ≤1Y and157 μSv for infants (1-2Y) ,which are lower than allowed value [13].

Alhawdaui . *et al*., in 2013 using gamma spectroscopy with such a NaI(Tl) detector, they analyzed overall particular action of ^{238}U, ^{232}Th, or ^{40}K in a range of legumes available for purchase in Iraq. Specific activity varied between 1.4500.096 through 12.3070.387 Bq/kg for ^{238}U in legumes, 0.371.058 to 9.2850.465 Bq/kg for ^{232}Th, with 64.0961.037 Bq/kg for ^{238}Ucompared to 603.3978.757 Bq/kg for ^{40}K. The findings were compared to international suggested levels and were determined to be within international standard [14].

Tareq A. and Tiruvachi N. 2013 in addition to the anthropogenic radioactive ^{137}Cs, they analyzed ^{238}U, ^{232}Th, and ^{40}K. Rice consumption in Kuwait is radio graphically safe attributed to the prevalence of the studied radionuclides [15], with estimated yearly dose levels of 33 and 60 Sv in children and adults, respectively.

Al-Hassan A. *et al*., 2014 studied ^{226}Ra, ^{232}Th, and ^{40}K in rice consumption in Saudi Arabia. The presence of ^{40}K in all samples in higher levels was anticipated due to its natural abundance. [16].

Ali Abid Abojassim *et al*., in 2014 studied ^{238}U, ^{232}Th and ^{40}K specific activity in different types of wheat flours that are available in Iraqi markets. The gamma spectrometry method with a NaI(Tl)detector has been used for radiometric measurements. It is found that the specific activity in wheat flour samples were varied from (1.086 ± 0.0866) Bq/kg to (12.532 ± 2.026)Bq/kg, for^{238}U, For ^{232}Th From (0.126 ± 0.066) Bq/kg to (4.298 ± 0.388) Bq/kg and for ^{40}K from (41.842 ± 5.875) Bq/kg to(264.729 ± 3.843) Bq/kg. Also, it is found that the of radium equivalent activity and internal hazard index in wheat floursamples ranged from (3.4031) Bq/kg to (35.1523) Bq/kg and from (0.0091) to (0.1219) respectively. But The range of summation of the Ingestion effective dose were varied from (0.0317) mSv/y to (0.5734) mSv/y [17].

Laith A. Najam *et al*., 2015 studied of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in rice consumed in Nineveh Province. NaI(Tl) detector was used to measure the radionuclides level. The radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from 51.15 to 109.26 Bq/kg,13.67 to 71.97 Bq/kg and 231.87 to 691.71Bq/kg. In order to evaluate the radiological hazard of the natural radioactivity, radium equivalent activity, internal and external hazard indices , and finally alpha index have been calculated . Hence rice consumption in Nineveh province Iraq is radiologically safe for the presence of the investigated radionuclides [18]

Abdalsattar K. and Hashim A.2015 studied alpha radioactivity concentration in ten various brands of rice was collected from Iraqi market by using alpha sensitive CR39 . The radon concentration and radium concentration in various brands of rice vary from 1.252 ×103 Bq/m3 to 23.110×103 Bq/m3 with an average 6.940×103 Bq/m3 and from 0.149 Bq/kg to 2.757 Bq/kg with an average 0.775 Bq/kg, respectively. The radon exhalation rates varied from 1.129 mBq/kg.h to 20.838 mBq/kg.h with an average 5.861 mBq/kg.h and surface exhalation rates from 20.268 mBq/m2 .h to 374.051 mBq/m2 .h with an average 105.212 mBq/m2 .h[19].

Fatimh A. in 2016 gamma-ray spectrometry was used to evaluate the activity levels of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs within wheat bread and bread samples. The results revealed that the mean value of a concentration levels in brown bread were greater than in wheat bread and white bread. The sequence of brown bread, white bread, and wheat flour demonstrates a declining tendency inside the average scores of their respective activities. Brown bread with more bran as well as other grains contained the greatest quantities of ^{232}Th. Nonetheless, their levels fell below the permitted limit [20].

Miha T. and Ljudmila B. 2017 determined the activity concentrations of particular radionuclides in infant formulas available on the Slovenian market. ^{238}U, ^{234}U, ^{230}Th and ^{210}Po activity concentrations were determined in five samples and dose assessment was carried out with dose coefficients listed in the IAEA. The results obtained show that the main contributors to the estimated cumulative radiation dose (230 to 350 µSv y−1) is ^{210}Po [21].

Khalid H. *et al*., in 2017 measured radon and uranium ability to focus in a set of advertising child's milk ingested in Iraq using nuclear path detector CR-39, the top value of pollutant concentrations in Dialak2 sample equivalent to (2607.3170 Bq/m^3) whereas the lowest value of pollutant concentrations throughout Dialak1 sample equivalent to (782.1950 Bq/m^3)

The present results indicate that the argon gas and uranium levels are within the International Atomic Energy Agency's (IAEA) 2 ppm [22] limit limits.

Riyadh A. and Abbas and A. in 2017 measured the radioactivity levels ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in 17 brands of flour consumed in Basrah, Iraq by using gamma-ray NaI(Tl) detector. For flour samples, the minimum specific activity values of ^{238}U, ^{232}Th, $^{40}K$and ^{137}Cs were 0.238±0.002 , 0.117±0.001 , 3.529±0.001 , and 0.040±0.007 Bq/kg respectively, while the maximum values of the same isotopes were 0.325±0.002 ,1.469±0.002 ,102.348±0.001 , and0.179±0.003 Bq/kg respectively. All achieved results have been found under the international limit standards. Thus, selected flour and macaroni types are safe to be consumed in Basrah governorate [23].

Tareq Alrefae *et al*., in 2018 the inherent radioactivity of Kuwaiti flour was examined. The activity levels of the three radioactive elements were determined being within normal ranges. In addition, the predicted lifelong cancer risk was determined to be much below the tolerable threshold. Therefore, our data indicate that radioactive safety of flour ingested in Kuwait again for three targeted radionuclides. Interestingly, there were statistically significant differences identified in the average activity concentrations that have been responsive to the wheat component[24].

Abdalrahman Alsalihi and Riyadh Abualhiall 2019 investigated the radioactivity levels of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in 13 brands of dry legumes consumed in Basrah, Iraq. By using gamma-ray NaI(Tl) detector .For lentils samples, the minimum specific activity values of ^{238}U, ^{232}Th and ^{40}K were 0.178 Bq/kg , 0.180 Bq/kg and 233.321 respectively, while the maximum values of the same isotopes were 2.594 Bq/kg 13.672 Bq/kg and 452.134 Bq/kg respectively. The averages of ^{238}U, ^{232}Th and ^{40}K in all lentils samples were 0.952 Bq/Kg, 3.325 Bq/kg and 331.804 Bq/kg respectively. Various radiation hazard have been determined for all samples. All achieved results have been found to be under the international limit standards [25].

Ihsan U. *et al*., 2020 measured the radioactivity concentration of ^{238}U, ^{232}Th, ^{40}K in 12 local brands of wheat flour retailed throughout Pakistan using a high-purity germanium detector. The specific activities of ^{238}U, ^{232}Th, and ^{40}K were found to be 5.7 6 0.41, 1.9 6 0.02, and 132.4 6 0.82 Bq.kg-1 , respectively. The mean values of the corresponding radiometric variables, Raeq and Hint were also found to be 18.651 Bq/kg and 0.313 mSv/ year respectively. The total mean annual effective dose due to the presence of the aforementioned radionuclides in the collected samples was found to be 213.1 μSv/year. The results were found to be below the recommended specific values and have no health risks for consumers [26].

Prasong Kessaratikoon. ***et al*,.2021**, 30 samples from glutinous rice procured from local shops or department stores in Songkhla Province were examined for the presence and activity of man-made radionuclides (^{137}Cs) as well as natural radionuclides (^{40}K, ^{226}Ra, and ^{40}Th). High purity gallium (HPGe) detectors with gamma-spectrometry analysis equipment were used by the Thailand Institute of Nuclear Technology's Laboratory to conduct experiments (TINT). It was found that the specific energy of ^{40}K and other radioactive elements in glutinous rice samples ranged form 592.21 to 896.36 Bq/kg, with an average of 683.13 Bq/kg for 30 samples. To round things off, the ELCR value and many other radiological danger indices were analyzed and confirmed to be within acceptable limits. Results are then compared to Organization of Nucleons for Peace (OAP) data, Thai research results, global studies and specific specified values [27] .

H. T. Abed elkader Zagazig. *et al* ., in 2022 for the first time, the activity of medicinal samples was examined. The studied medicinal plants had average activity values of 7.25, 7.78, & 471.4 Bq/kg, respectively. External and internal exposure to NORMs were observed to result in yearly dose levels of 0.1579 and (0.0373) mSv, respectively (outside the residence, in the door). In addition, we concluded that the data are consistent with UNSCEAR [28].

Esam S. Ali ,*et al*.,2022 in this work, ^{232}Th, ^{40}K, and ^{238}U specific activities were assessed in dietary samples. All findings indicated that almost all values were within internationally acceptable range. In addition, the rates of radioactive hazard effects as measured by the radium equivalent efficiency, its internal hazard index, and the yearly effective dose in packaged food are below the internationally allowed level (Radiation Safety Centre, Radiation Control Department [29].

1.3 Aims of the study

The study aim to measur the radioactivity of (^{238}U) , (^{232}Th) and (^{40}K) in various samples of food available in the Iraqi markets as well as calculating risk factors. And then comparing the results with international levels and other studies globally and locally.

Chapter Two

Theoretical Part

2.1 Introduction

Henry Becquerel discovered in 1895 while studying phosphorescence that some salts leave a black mark on a photographic panel, even if it is completely obscured from the light, as it happens to contain uranium, which means that these substances emit a new type of radiation and that they are not X-Ray rays, because the material does not need to provoke the externality of this phenomenon called radioactivity**.**

In 1898 Marie Curie and her husband Pierre Curie were able to isolate of two previously unknown toxic elements (Radium, Polonium) after which many other elements were discovered, these discoveries prompted many scientists to understand the phenomenon of radioactivity, it must be emitted from the nucleus of the atom as a result of the dissolution of unstable nuclei[30].

In the early era of radiation discoveries, scientists did not know the dangers of this radiation, but after a while they observed that many miners exposed to Radon (resulting from uranium or thorium isotope decay) had been infected with the deadly lung disease recently diagnosed with cancer, after which efforts to prevent radiation exposure in Europe and the United States International Radiation Prevention Commission on Radiological Protection were developed in 1913-1916 under the auspices of the National Committees for Radiation Prevention (ICRP). International committees such as the Committee and the National Council for Radiation Protection (NCRP) have been formed and the United Nations Scientific Committee on Effects on Atomic Radiation has been formed, which was established from 20 Member States and a group of scientists from those countries specializing in the fields of radiation physics and biological effects of radiate ion participate annually to study all scientific and statistical aspects associated with ionizing radiation and the spread of these government institutions have been interested in publishing and implementing laws and instructions on radiation prevention[31].

2.2 Radiation sources

Can distinguish between natural and man-made radiation sources[32], that natural and industrial radiation sources directly contribute to increasing the radiation dose of humans, and that natural radiation sources, contribute about 81% of the annual radiation dose to the general population as shown in figure (2.1) sources of radiation from human medical, commercial and industrial activities contribute 19% of the annual dose, mostly from medical uses of radiation, which include treatment, diagnosis, radiology and nuclear medicine[33,34].

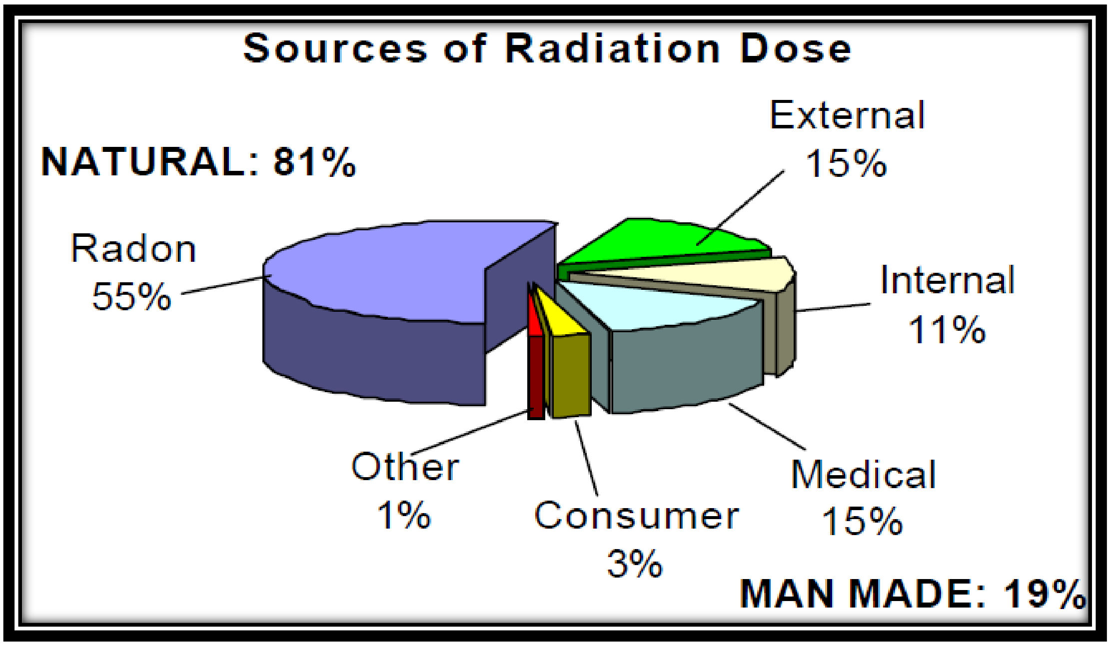
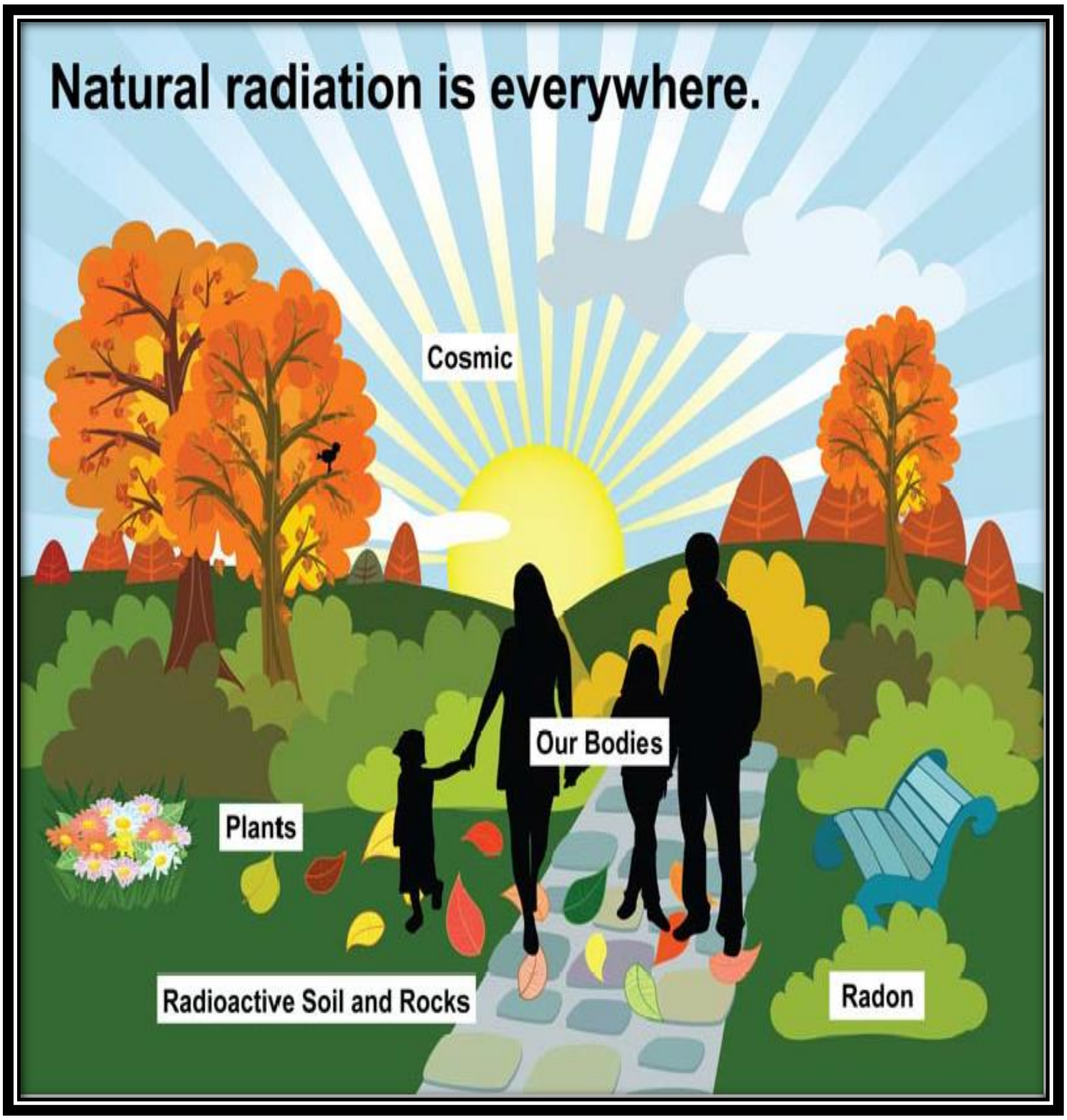


Figure (2.1): Radiation Sources [33]

2.2.1 Natural Radiation Sources

Natural back radiation is present everywhere around us in different forms as shown in figure[34,35] (2.2). Levels of exposure to natural posterior radiation can vary greatly.



Figure(2.2): Natural Radiation Sources [34]

The main sources of natural radiation are cosmic ray, ground radiation and Radioactivity in the body [33].

2.2.1.1 Cosmic Ray

These rays are emitted from outer space and are produced from stellar accidents in distant cosmic space, including from the sun, especially during solar flares that occur every 11 years, but most of these rays are absorbed from the outer atmosphere of the earth, which acts as a radiation shield and we receive only a small part of it. 87% of these rays are composed of protons, 11% alpha particles, 1% heavy nuclei, and 1% electrons, and the energy of this beam ranges from 10 MeV to 100 GeV [36].

2.2.1.2 Terrestrial Radiation

Contains rocks and soil of the earth's layers on many radioactive isotopes that date back to the moment the universe was created 4 billion years ago, and since then all the nucleotides with half-short ages have dissolved. Nucleotides with very long half-life’s (100 million years or more) remain until now, including natural radionuclides such as uranium and thorium and their daughter[37] .

2.2.1.3 Radioactivity in the Human Body

Food and inhaling air contaminated with naturally occurring radionuclides leads to the receipt of a radiation dose that changes significantly depending on changing geographical location, type of food and habits[38]. The biggest contributor to this dose is (^{40}K) due to its high abundance in nature and its large concentration in human tissues as there is 140g of potassium in the body of an adult weighing 70kg. Other nucleotides in the human body are present in smaller quantities and include radium and thorium sequences[39],the gaseous breakdown of nuclear uranium sequences, radon and thoron, contributes actively to radioactivity in the body**.**These gases are spread through rocks and soil and appear in the atmosphere with easily measured concentrations as they enter the human body through breathing and with them the products of decomposition as well as taken from plants and animals and as a result most food contains quantities of natural radioactivity that can be measured for normal food, as grains have a high quantity of radioactivity compared to milk products, fruits, and vegetables, overall absorption of the this kind of radioactivity varies [38,39]. The human body is often dependent on food type and geographical location.

2.2.2 Artificial Radiation Sources

Medical operations including such x-ray diagnostics, nuclear medicine, and radiation treatment are the most significant route of contamination to industrial radiation. I-131, Co-60, Ir-192, Cs-137, Tc-99, and others are some of the primary isotopes used in medical areas. Consumer products, such as tobacco, construction materials, combustible fuel (gas, coal, etc.), glass, televisions, lighted timepieces, airports x-ray scanners, smoke alarms (americium), highway building materials, electronic pipes, and fluorescent lamps are additional sources of industrial radiation. The general populace is exposed to ionizing radiation as a result of a nuclear fuel cycle, that involves a variety of nuclear mining and milling procedures, as well as radioactive materials from the manufacture of nuclear fuel, the operation of nuclear power plants, the storage and filling of radioactive waste, weapons, nuclear accidents, etc [40].

2.3 Radioactivity

Radioactivity is an automatic decay (or disintegrate decay) of the peer's nuclear vessel with the release of nuclear particles such as alpha or beta particles, which may be followed by the release of gamma radiation. Isotopes in which this disintegration or decay occurs are known as radioactive isotopes, and radioactivity is defined as a certain type of radiation emitted from radioactively active substances, and elements in nature (earth) have radioactivity [41].

2.4 Types of Radiation

Radiation types can be classify due to charge, mass, but one of the most important classifications is the amount of energy, low-energy radiation is called non-ionizing radiation, while high-energy radiation is called ionizing radiation [42].

2.4.1 Non-Ionizing Radiation

A type of electromagnetic radiation that has long wavelengths and low photon energy and this energy is sufficient to move atoms around particles of matter or cause vibration, but they are insufficient to uproot electrons such as radio waves, microwaves, and visible light [43].

2.4.2 Ionizing Radiation

Ionizing radiation compared to other radiations can deposit a large amount of energy in a small area, so all ionizing radiation is directly or indirectly able to remove electrons from most atoms, and these radiations may be as particle as alpha, beta and other or electromagnetic particles such as X-rays and gamma rays [44] .

2.4.2.1 Alpha Particles

Rutherford and Royds were credited with discovering alpha radiation. It is comparable to atoms of helium that include protons and neutrons. These four particles are coupled to a nuclear force in such a way which the alpha particle acts in multiple places as if it were one fundamental particles and alpha particle mass has four atomic mass units and two electrical charges [38].

2.4.2.2 Beta Particles

Beta radiation(β) consists of electrons emitted from the nucleus at high velocity. These nuclear electrons possess identical properties as electrons, including a mass of 1/1840 atomic mass units and a single negative electrical charge. Anderson discovered another form of beta radiation in 1932. This radiation is made up of particles with same mass as an electron and has one positive electrical charge called positron radiation. Although less important than negative beta particles from the point of view of radiation prevention, positron knowledge is necessary for the purpose of understanding the specific radiation degradation mechanism [38].

2.4.2.3 Gamma Ray

Gamma rays are electromagnetic rays emitted from natural and industrial radioactive sources in the form of photons that do not have a charge, so they do not deviate from the electric field and magnetic field as they have a high penetration capacity and a longer range of material compared to alpha and beta particles[45] The process of emitting gamma rays from radioactive isotopes is one way in which irritating nuclei are eliminated from some or all of their energy by moving from a high to a lower level, the distinction between the 2 levels equals the energy of the photon emitted, and as the energy of gamma radiation varies from nucleus to nucleus, every photon energy emitted by such a component is a feature of that element [46].

2.4.2.4 X–Ray

X-rays were discovered in 1895 by German physicist William Conrad Rontgen. X-rays belong to the electromagnetic radiation group and are similar to light, radio waves and gamma radiation. It doesn't have a mass or charge, but it has a wavelength that depends on its energy and differs from gamma rays by two important points. First, gamma rays originate from atom cores while X-rays arise from changes in electron orbit. Second, gamma rays from a particular source have specific separate (distinct) energies, but X-rays usually have a wide spectral range of energies up to some distinct maximum values [38].

2.4.2.5 Neutrons

Neutrons and protons are both constituents of the nucleus' core. Neutrons are nearly identical to proton in mass and size, but lack an electrical charge. Neutrons and protons often coexist within the nucleus, and the amount of protons and neutrons determines the nucleus' mass number.

The nucleus in nature, which is unstable due to the increase in neutrons compared to protons, will change this ratio by turning neutron into proton within the nucleus with the release of negative beta particles instead of a neutron release[47].

2.5 Interactions of Gamma Radiation with Matter

Gamma rays were photons that emanate from the decaying nuclei of radioactive atoms. They lack mass and electrical charge. It can fly unimpeded over great distances in the air. Understanding how gamma photons are recognized and muted in detectors requires an understanding of how gamma rays interact with detector scintillation material. When gamma radiation interact with matter, they can be entirely absorbed or scattered by an atom or a nucleus via a variety of processes. A gamma ray can interact with materials via the Photoelectric effect and Compton scattering [48].

Gamma rays are emitted during nuclear transitions. Complex processes are performed during the passage of gamma rays through the material, and in theory there are twelve stages of absorption and citation of gamma radiation that are possible within the material. However, many of these stages are rare and some are difficult to observe, and the most frequent interactions within the energy limits of (10KeV-10 MeV) have been found to be PV, Compton esta and electron pair production – positron[49]

2.5.1 Photoelectric effect

It is one of the reactions of gamma radiation to the material as a result of the direct collision between the dropped photon and one of the electrons associated with the inner orbits of the atom, the photon energy is transmitted to that electron that releases, leaving the atom, and this electron emitted by the photon is called the Photoelectric, which gives the kinetic energy of the electron released in the following relationship [50,51].

$$T_e = (h\nu) - B_e - T_a \qquad (2.1)$$

$h\nu$: The energy of the dropped gamma rays.

B_e: binding energy (electron link energy in atomic orbit)also called work function.

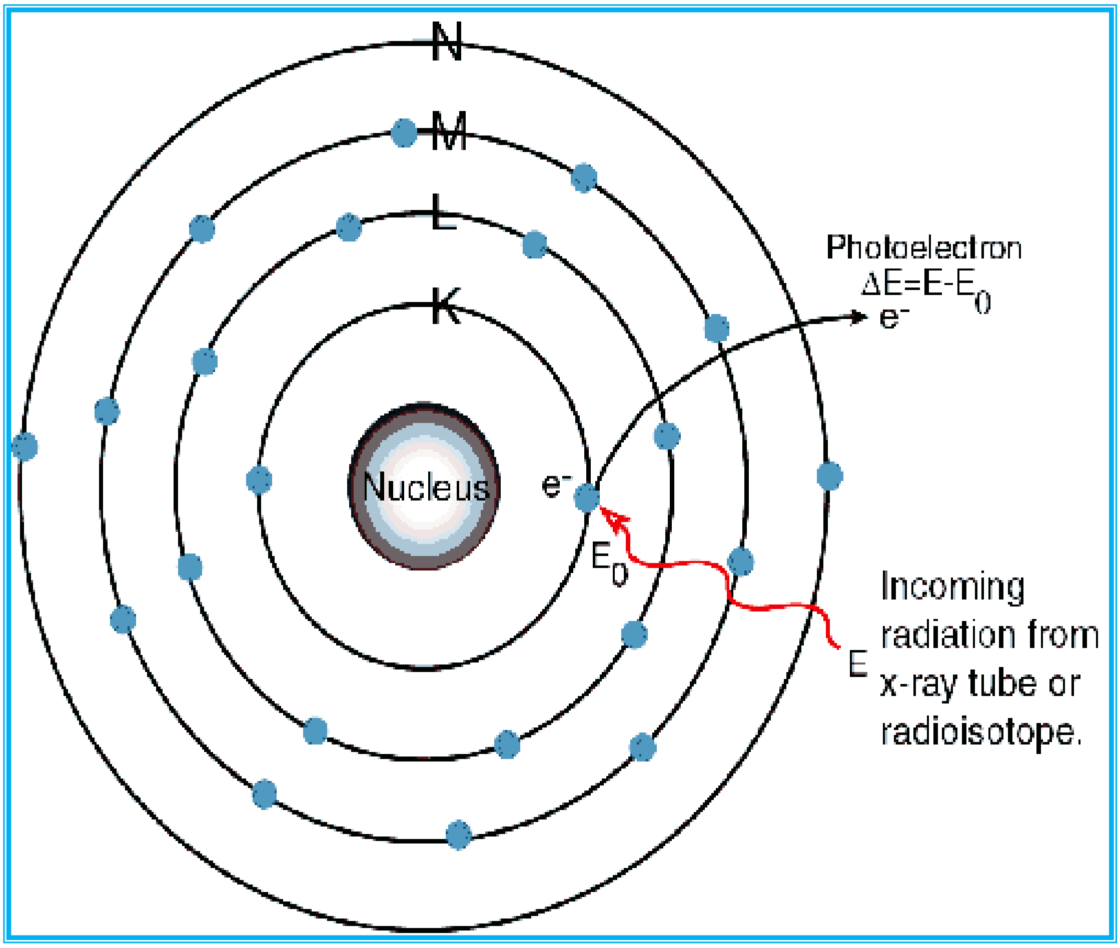
T_a: Recoil energy atom

And since the atom's recoil energy is small because the electron mass(m_e) outside is much lower than the(M)atom mass therefore, it can be neglected according to the following equation[51,52]

$$T_a = \frac{m_e T_e}{M} \tag{2.2}$$

Thus, the energy of the electron abroad will be equal to:

$$T_e = h\nu - B_e \tag{2.3}$$



Figure(2.3): Photoelectric Effect

2.5.2 Compton Effect

Compton's catheter occurs when a γ-ray reacts to a particular card with the free electro which has little atom-related energy relative to the high (gamma ray energy) As a result of the interaction between the fallen photon and the free electron (weakly associated) that has a m_o. stillness mass, the electron will acquire a portion of the photon's energy and be released from the atom, while the rest is carried by the photon at an angle (θ) and as in figure (2.4).

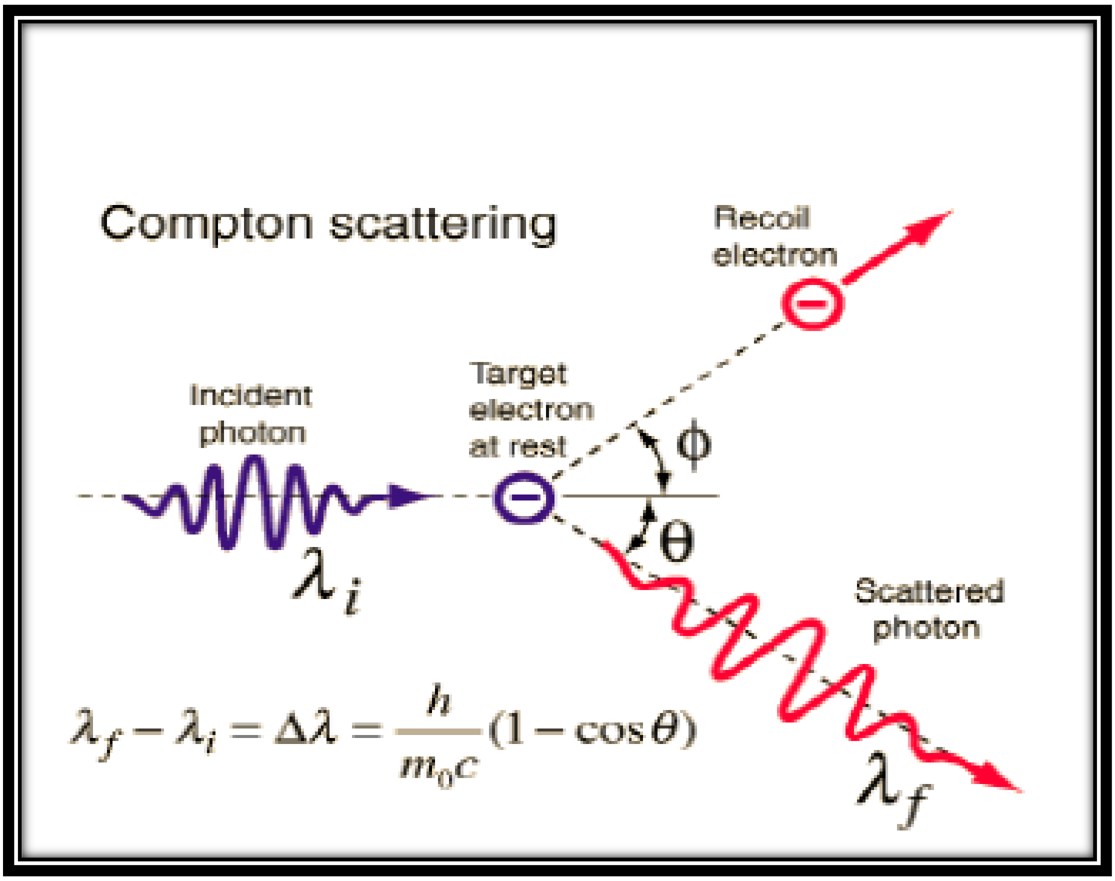


Figure (2.4): Compton Effect [51]

The maximum energy of the electron appears when the photon is subject to a 180° -degree citation, The kinetic energy acquired by electron (T_e) can be calculated in the following relationship[53].

$$T_e = E_\gamma - E_\gamma{}' \qquad (2.4)$$

E_Υ: photon's energy

E_Υ : The energy of the photon that gives the following relationship to all the corners of the rain except $\theta = 0$ [53].

$$E_\gamma{}' = \frac{m_o c^2}{(1-\cos\theta)} \qquad (2.5)$$

$m_o c^2 = 0.511$ MeV is the static energy of electrons

θ: Angle between falling gamma rays and scattering gamma rays [50]

2.5.3 Pair Production

This interaction occurs in the nucleus field of the material of the absorbed medium and at this site the electron-positron will arise, as the photon disappears completely.

The energy needed for this phenomenon to occur is ($2m_o c^2$) which is the threshold energy. If the photon energy is greater than that, $E_{hv} > 1.02$MeV, the excess energy will be the kinetic energy of the emerging particles. This can be expressed in the following equation[54]:-

$$E_{e^-} + E_{e^+} = h\nu - 2m_o c^2 \qquad (2.6)$$

The excess gamma ray energy is transmitted from ((1.022 MeV) To electron kinetic energy (e^-) and positron (e^+) ,after slowing down the positron to low energy, it combines with a nearby electron and the two are composed of two gamma-card photons (0.511 MeV) and two opposite directions, and the pair's production increases with the atomic number box of absorbent material and the gamma ray energy [53].

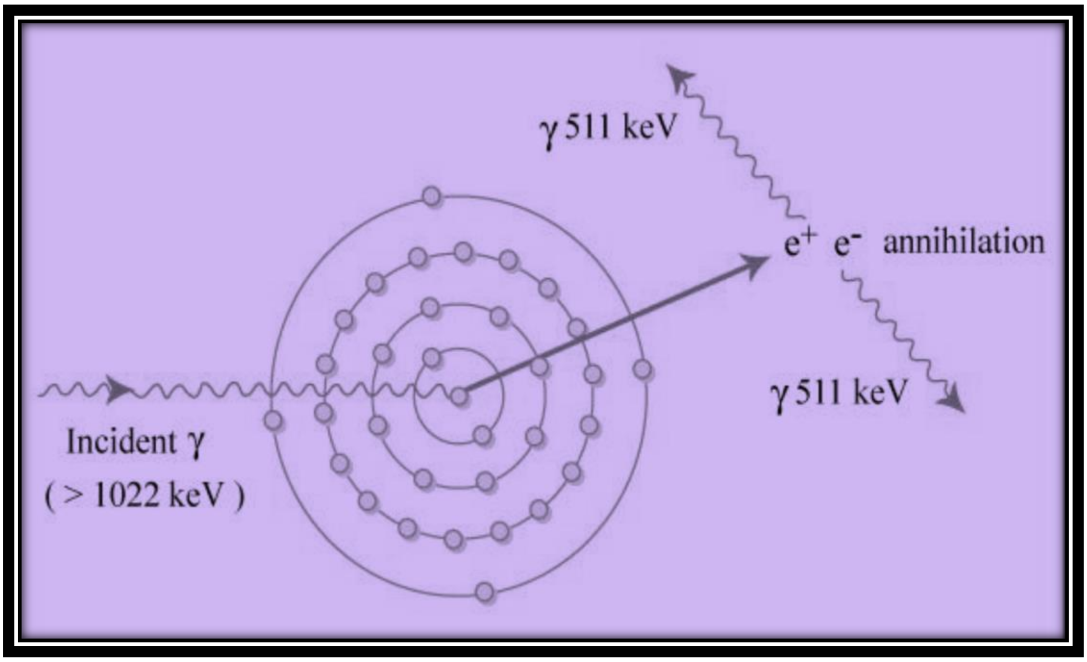


Figure (2.5): Pair production electron - positron [51]

The inverse of this process can also occur when the electron meets the positron it will fades away each other and each other forming a pair of photons, the two resulting photons are heading in opposite directions in order to legally achieve the conservation of energy and momentum, and there is no need for a nucleus or body in the process of annihilation[55].

2.6 Radioactivity Series

The cores with an atomic number greater than (82) are radioactive due to the increase inside the number of protons in the nucleus, which increases the power of electrostatic dissonance. This incongruence leads to the disintegration of some cores with release of alpha particles, that also causes an increase in the ratio of neutrons to charged particles in the nascent cores, which causes their disintegration with the release of beta particles, and so on. Continues to reach a stable nucleus, typically the nucleus of lead, In nature there are four groups known as natural radiation chains: the uranium chain, the actinium chain, the thorium chain, and a fourth series, the neptunium Series, and table (2.1) shows the most important characteristics of these chains [56].

Table (2.1): Properties of radioactive chains[61].

Series names	Series end	The longest-lived nucleus in the chain and its half life	
Uranium	^{206}Pb	^{238}U	$4.47*10^{9}$year
Actinium	^{207}Pb	^{235}U	$8.04*10^{8}$ year
Thorium	^{208}Pb	^{232}Th	$1.41*10^{10}$ year
Neptunium	^{209}Bi	^{237}Ne	$2.2*10^{6}$ year

2.6.1 Uranium Series

Uranium ^{238}U is 99.25% of natural uranium, which decomposes with a massive alpha emission to become thorium (^{232}Th) , which in turn is common, and also decomposes with a massive negative beta emission and converts to protactine (^{234}Pa) and the chain continues to decompose until it reaches the stable lead counterpart of (^{206}Pb), and the general formula of mass numbers (4n+2) where (n) is a valid .evidence of the presence of(^{238}U)in the model it contains during the measurement of γ rays resulting from its dissolution, or the measurement of α rays resulting from the dissolution of its ^{222}Ra. The figure (2.6) shows the uranium chain(^{238}U) [57,58,59].

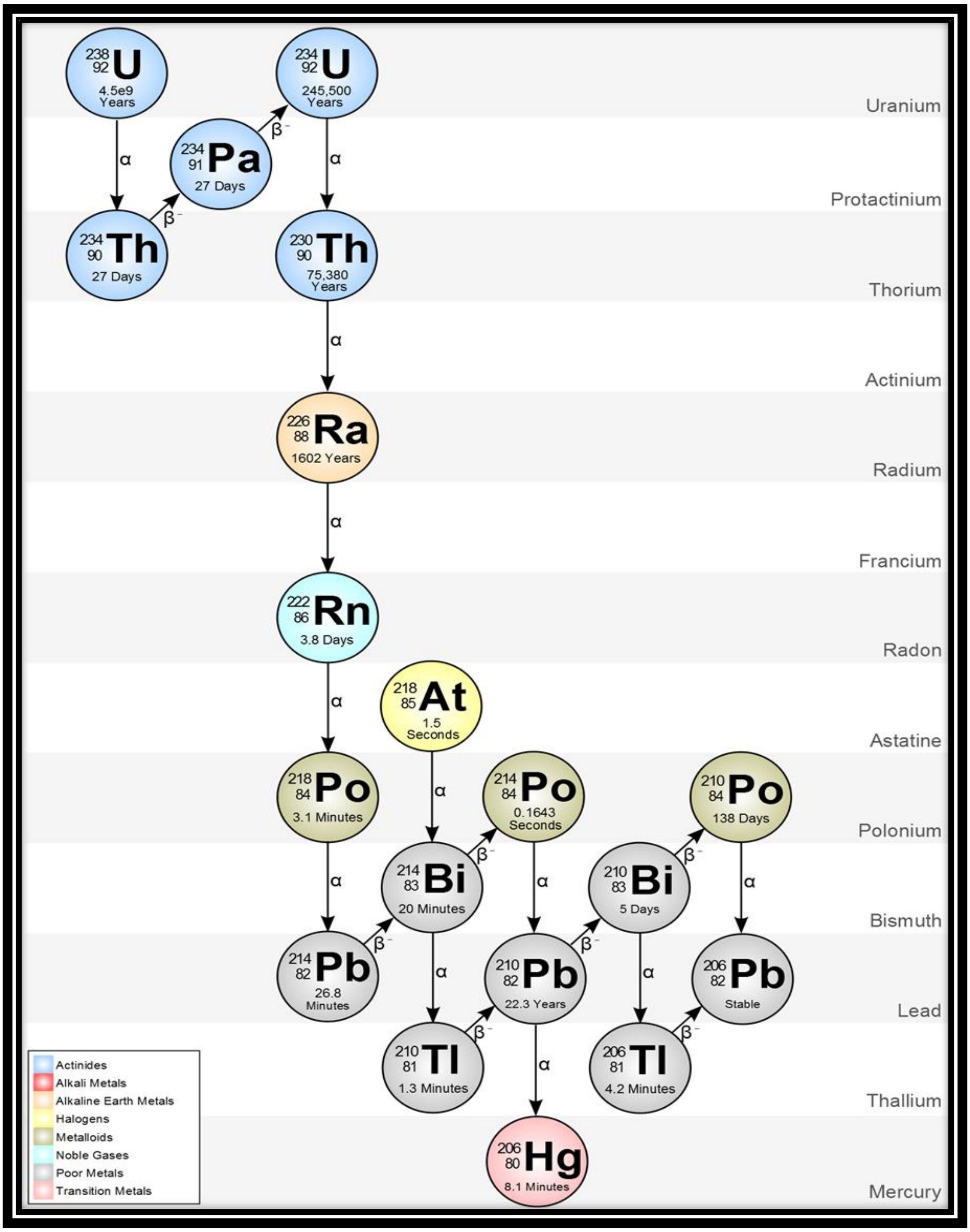
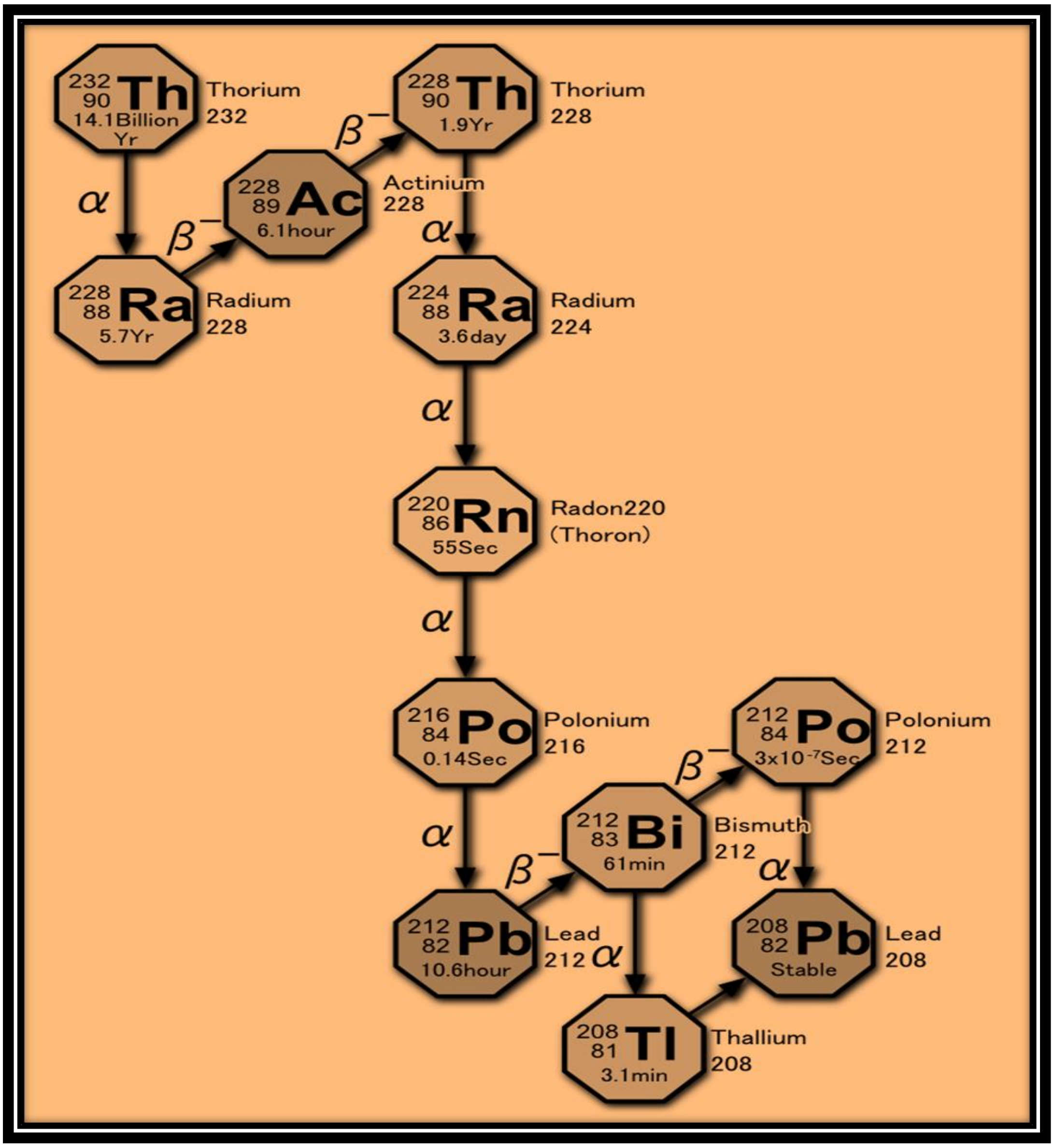


Figure.(2.6) Uranium Series U-238 [59]

2.6.2 Thorium Series

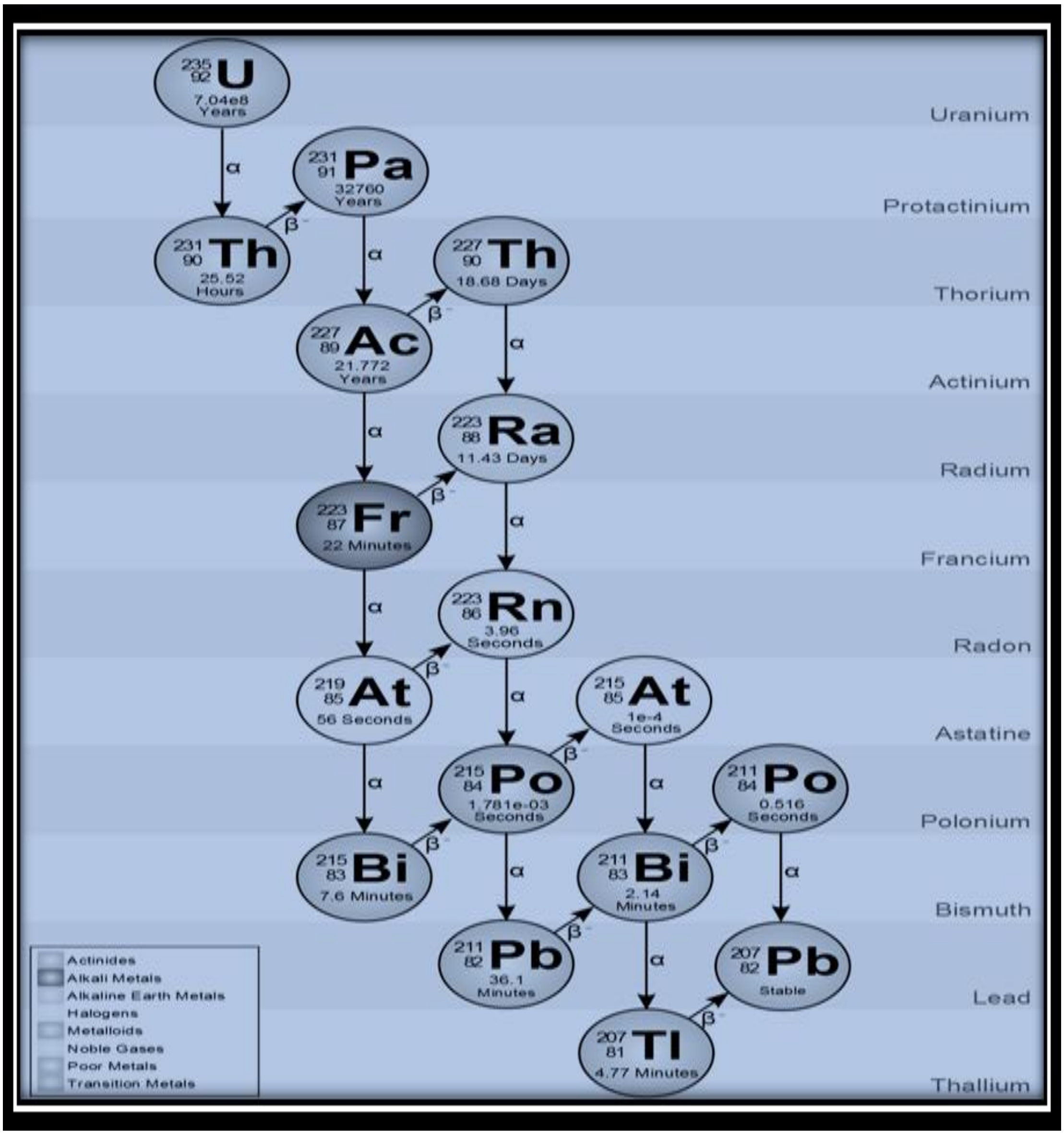
There is an abundant thorium in nature (%100) and this series begins with (^{232}Th) and suffers a number of dislocations to end with lead-208 (^{208}Pb), as in Figure.(2.7) [58,59,61] each member of this series has a mass number of a multiples of number 4, so the A=4n this series is about six times longer than earth [6**0**].



Figure(2.7): Thorium Series (Th-232) [59]

2.6.3:Actinium Series

The Uranium-235 series is called the actinium series or the 4n+3 series, and uranium is ^{235}U (0.72%) of uranium, starting with uranium-235 and ending with a stable lead-207 component, as described as figure (2.8) [56,57,59]. This series is the only series found in nature that is activated by× slow neutrons. The most important element is ^{235}U (half-life old 7.04×10^{8}yr [60].



Figure(2.8): Actinium Series (U-235) [59]

2.6.4 Neptunium Series

This series is not present in nature, as the half-life of its longest element is (2.2×10^6yr), which is much smaller than the earth's estimated age of (4.5×10^6yr), meaning that it has been transformed into stable cores, the bismuth cores- 209.[53] This series begins with the parent core ^{237}Np (the longest-lived core) and is the only one that ends with a stable ^{209}Bi bismuth counterpart instead of lead [57] The figure. (2.9) shows the neptunium chain.

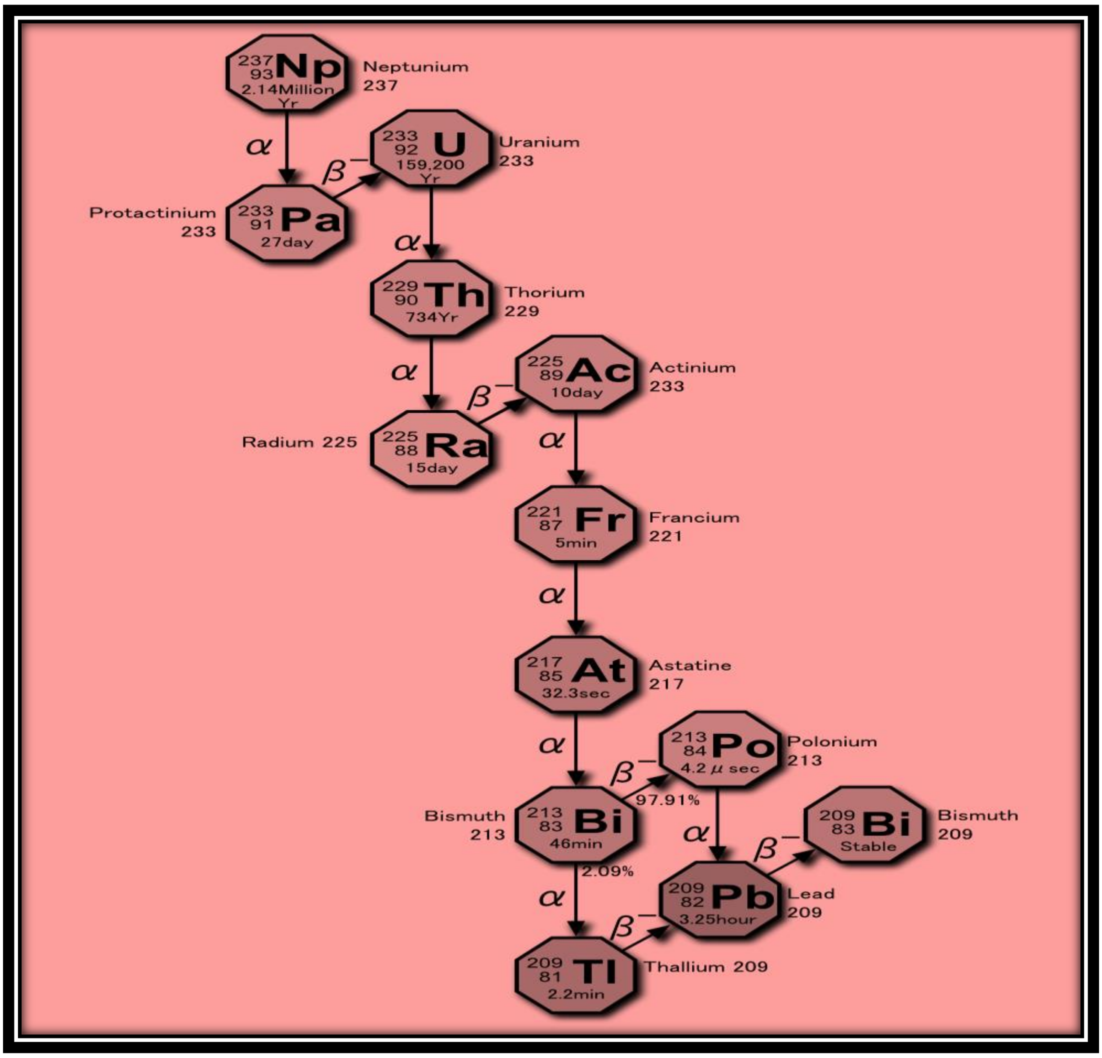


Figure (2.9): Neptunium Series [59]

2.7 Radioactivity Decay Law

Let's assume that we have a number of nucleus *N* and after a time period of *(dt)* a number of the nucleus *(dN)* may decompose and produce the equation:

$$-dN \propto Ndt \tag{2.7}$$

The negative signal means that there is a shortage of radioactive cores. So that

$$-dN = \lambda Ndt$$

λ :disintegration or decay constant It represents the possibility of the dissolution of any radioactive nucleus in the unit of time, or part of the nuclei found in particular sample that dissolves in the unit of time [61,62]. therefore the decay constant can be written as follows:

$$\lambda = -\frac{(dN/dt)}{N} \tag{2.8}$$

by calculate on the number of N(t) radioactive cores in any time period we get the law of dissolution, the law of dissolution. Using the equation (2.8) as follows:

$$\frac{dN}{N} = -\lambda dt \tag{2.9}$$

$$\int_{N_0}^{N} dN/N = -\int_{t=0}^{t} \lambda dt \tag{2.10}$$

N_0 : Is the number of total radioactive cores present in time t = 0. and by integrating, we get

$$LnN(t) - LnN_0 = -\lambda t \qquad (2.11)$$

$$Ln(\frac{N(t)}{N_0}) = -\lambda t$$

$$N(t)/N_0 = e^{-\lambda t} \qquad (2.12)$$

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

This law can thus be written in the alternative of radiation effectiveness

$$Activity(A) = -\frac{dN}{dt} \qquad (2.13)$$

$$A = -\frac{dN}{dt} = \lambda N$$

Specific Activity Radioactivity (A) can be obtained from the equation (2.12) by multiplying both ends with the decay (λ) [60,62]

$$A(t) = A_o e^{-\lambda t} \qquad (2.14)$$

2.8 Radioactive Equilibrium

Can get a balance when the parent nucleus decomposes with much less decomposition constant than the rest of the chain. That is, the parents half-life is bigger than the half-life of her outputs[63], this balance has several situations.

2.8.1 Secular Equilibrium

This balance occurs once in the age of the nucleus and continues to the end and occurs in one case, which is when the age of half of the parent nucleus is much older than the age of half of the daughters nucleus, as the radioactivity of the parent nucleus is equal to the radioactivity of the daughters nucleus and the balance law is given in the relationship that follows [64].

$$\lambda_P N_p = N_D \lambda_D \qquad (2.15)$$

N_p: The number of atoms for parent

N_D : The number of atoms for daughter

λ_p, λ_D : Constant radiation decay for both the parent nucleus and the daughter.

This condition is common in measuring the normal radioactivity of naturally occurring nuclides such as uranium, thorium, and potassium, and is measured only after the daughter. nucleus reaches the state of eternal balance and figure (2.10) showing the state of eternal balance [64,65].

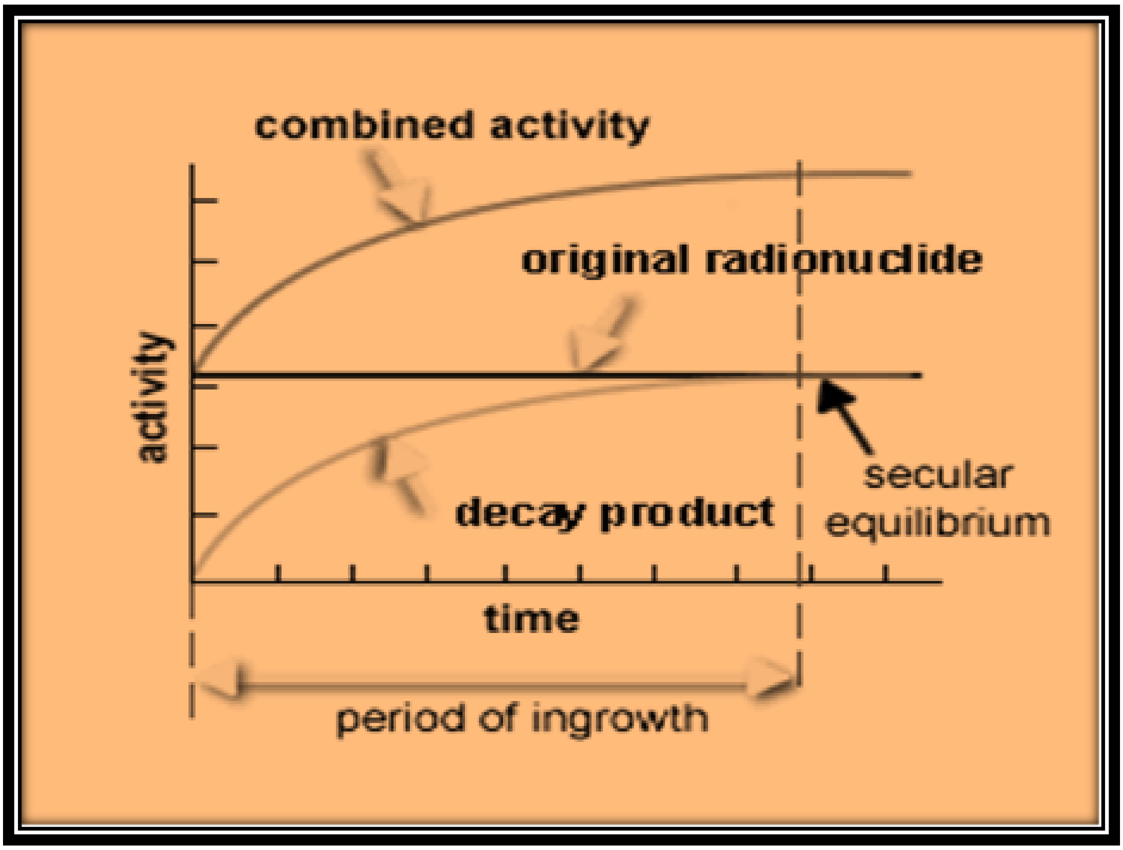


Figure (2.10): Secular Equilibrium [65]

2.8.2 Transient Equilibrium

This balance occurs when the age of half of the parent is slightly greater than the half-age of the daughters intentions, which leads to the fact that the radioactivity of the daughter intentions exceeds the radioactivity of the nuclear after a period of time as follows [64,65].

$$N_2\lambda_2=N_1\lambda_1+N_2\lambda_1 \qquad (2.16)$$

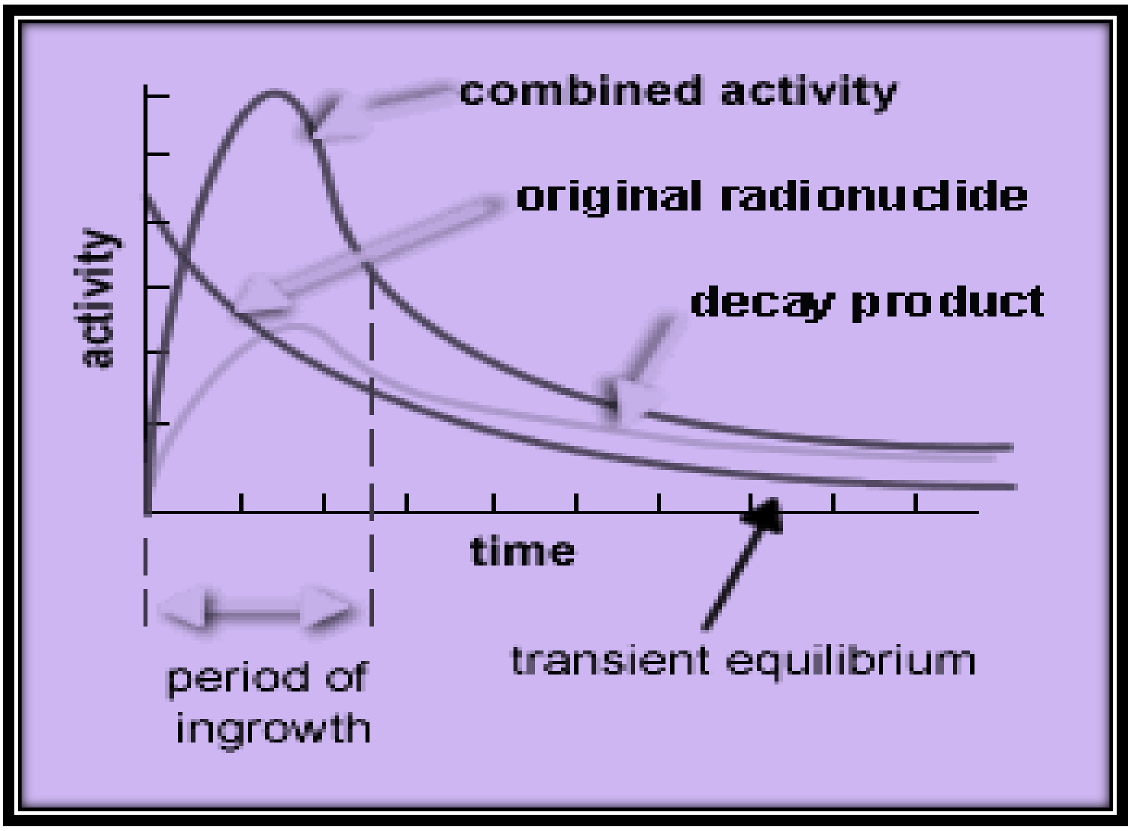
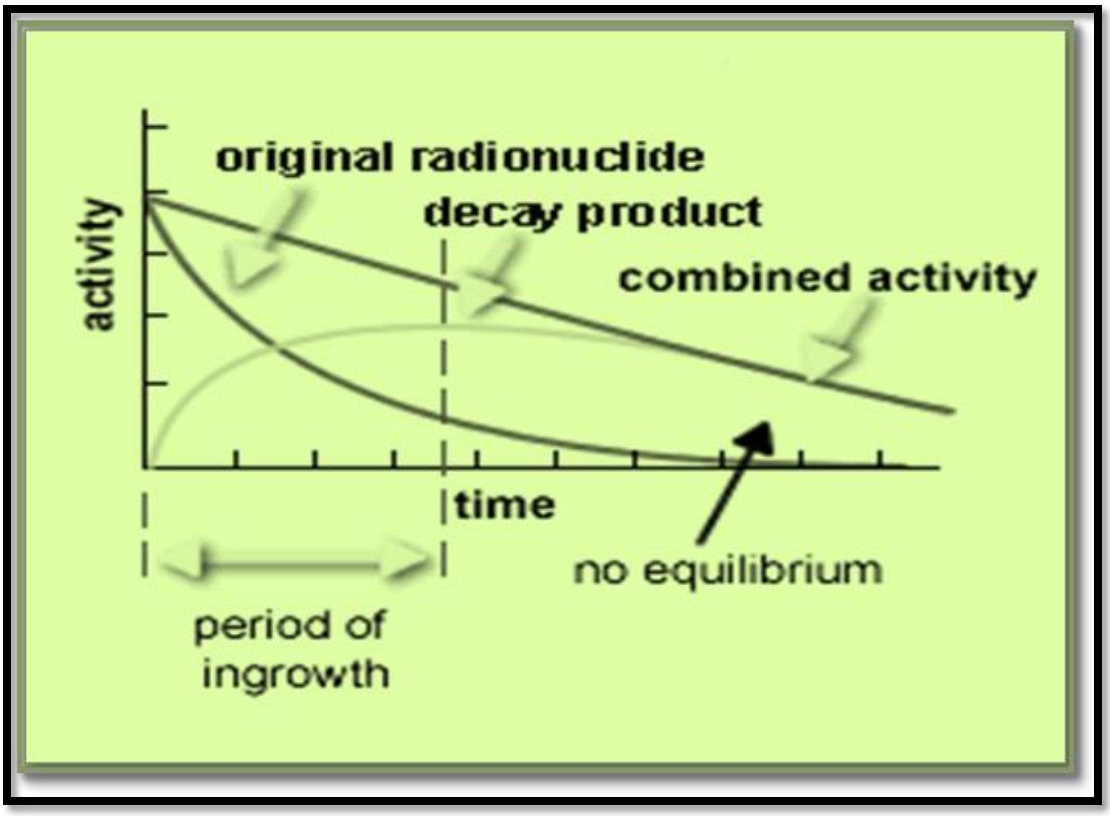


Figure (2.11) :Transient Equilibrium[65]

2.8.3 Non Equilibrium

If the parents half-nucleus is younger than the half-age of the daughter nucleus, in this case the parent nucleus will dissolve, leaving the daughter nucleus alone, in other words, the effectiveness of the daughter nucleus will increase until the number of atoms runs out of the parents nucleus and then the effectiveness of the parent nucleus will decrease over time and there will never be a balance in this case as shown in the figure(2.12) [66,67]



Figure(2.12): Non Equilibrium[65]

2.9 Radiological Detectors

The devices used to detect nuclear radiation have evolved with the development of the subject of nuclear physics. These detectors were used to detect nuclear radiation and to measure its energy, in both cases the detection method depended on the interaction between radiation and the detector material. These devices detect charged particles directly, and uncharted (equivalent) particles such as neutrons are detected indirectly through charged particles and material atoms [68] the multiple types of reagents perform different purposes, and each detector has its advantages and problems, there is no detector that can be used for all purposes, but we find that each detector has a certain characteristic that has a high ability to analyze energy but at the expense of efficiency, and all reagents share the form of collecting information from radiation interaction with detector material but differ in the way this information is collected and how it is recorded, these methods to name a few. Editing and assembling shipments on the right pole, such as gas reagents and semiconductor reagents, or editing electrons and using a photo methyroid to obtain an electronic pulse, such as in flash reagents, thus varying the method of gathering information according to the detector.[56]

2.10 Gamma Ray Detection

The work of nuclear detector used to detect gamma rays depends on the type of interaction that occurs between those rays and the detector material, as the importance of reactions for gamma ray detectors lies in how the pulse capacity coming out of the detector depends on the amount of gamma ray energy absorbed in the detector material, and these mechanisms differ from each other by adopting photon energy mainly gamma radiation detection techniques are widely used in gamma radiation spectra and are used in nuclear physics, health physics, soil science, neutron activation analyses and cosmic radiology the NaI(Tl) sodium iodide detector is widely used among many nuclear reagents to detect gamma photons as fit, effective and highly efficient, as well as cheap [56].

2.11 Calculation of Specific Activity

Specific activity can be calculated through the following equation[69]:

$$A = \frac{N_{net}}{\varepsilon.I.m.t} \pm \frac{\sqrt{N_{net}}}{\varepsilon..I.m.t}[Bq.kg^{-1}] \qquad (2.17)$$

N_{net}: The area under the top curve after subtracting the radiation background

ε: detector efficiency

I: the coefficient of concentration of effectiveness, t: measurement time (sec) m: sample mass (kg)

2.12 Internal hazard index

Intake of alpha particles released by short-lived isotope such as radon and explosions associated by gamma rays are distinct cards that can be described as an alternative to the intrinsic risk factor (H_{in}) and computed using the continuity formula [67].

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2.18)$$

The amount of internal risk is preferred to be less than one in the ideal environment for proper working opportunities for respiratory organs and for individual living [70].

2.13 External hazard index

The external risk evidence is assessed for the risk of natural gamma radiation and is calculated from the following equation.[71]

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2.19)$$

Where these plants must be less than one, if they are equal to one or greater than one, indicate a radiation risk [72].

Chapter Three

Experimental Part

3.1 Introduction

This chapter includes the steps of collection and preparation of samples to calculate the levels of natural radioactivity of different types of food, also includes the statement of the nuclear counting and analysis system used in this study such as: the preparation of the system of energy calibration, efficiency and laboratory measurement of the radiation background.

3.2 Collection of Samples

Forty-three samples of various types of food, including rice, legumes and wheat flour, were collected from Iraqi markets to scan and calculate levels of natural radioactivity.

All the samples were packed in plastic (polyethylene and identified symbols by their country of origin, the samples were dried in an oven to achieve a constant weight, then crushed electronically with an electric mill and mesh sieve (0.8mm pore size sieve) to ensure homogeneity. The samples were put in (750g) plastic (Marinelli containers) of fixed volume (the containers prior to use were washed with distilled water and programmed to distinguish between samples), and their corresponding net weights have been measured and recorded using a highly sensitive digital relative weight (using an extremely sensitive digital weighting balancing act with an accuracy of 0.05 percent). The Marinelli beakers then were completely sealed for at least four weeks to reached radioactive equilibrium between parents and their daughter radio nuclides, as shown in the figure,(3.1).

Figure(3.1) : A typical Marinelli Beaker Filled with a Samples

The procedure of samples collection and preparation used in track technique was similar to that applied in NaI(Tl) method, food sample tables were made according to the name of the sample, country of origin and production date, and a special code was developed for each sample and the samples were divided into groups including the rice group, the dry legumes group and the wheat flour group as shown in the tables (3.1),(3.2)and(3.3)

Table (3.1):Rice samples information sample code,name of sample,orgin and packing date

Sample code	Names Sample	Origin	Packing date
R_1	Joker	India	04\2021
R_2	Gul Bahar	India	01\2021
R_3	Vietnam Rice	Vietnam	04\2021
R_4	Elegant	India	04\2021
R_5	Abo Hosan	India	02\2021
R_6	Thailand Rice	Thailand	04\2021
R_7	Sella Rice	India	07\2021
R_8	Royal Stallion	India	04\2021
R_9	Bashan	India	06\2021
R_{10}	Abu Eagle	India	04\ 2021
R_{11}	Saman	Uruguay	01\2021
R_{12}	Mahmood Rice	India	04\2021

Table (3.2):Legumes samples information sample code,name of sample,orgin and packing date

Sample code	Names Sample	Origin	Packing date
B_1	White Beans	Canada	01/2021
B_2	Alt Unsa Beans	Argentina	04/2021
B_3	Nawras Beans	Argentina	09/2020
B_4	Cowpeas	Madagascar	11/2020
B_5	Cowpeas	Russia	01/2021
B_6	White beans	Turkey	03/2021
B_7	Alt Unsa Beans	Madagascar	11/2019
B_8	Crushed beans	Madagascar	12/2020
B_9	White Beans	Kyrgyzstan	05/2021
B_{10}	White Beans	Egypt	06/2021
B_{11}	Popcorn al tunsa	Argentina	07/2021
L_1	Red Lentils	Canada	12/2020
L_2	Green Lentils	Russia	04/2021
L_3	Zer Lentils	Canada	12/2020
L_4	Alt unsa Lentils	Turkey	10/2020
L_5	Peas Alt unsa	Argentina	06/2021
H_1	Altunsa Chickpeas	Mexico	07/2020
H_2	Crushed Chickpeas	Ukraine	03/2021
H_3	Chickpeas	Turkey	05/2020
H_4	Nawras Chickpeas	Mexico	06/2020

Table (3.3):Flour samples information sample code,name of sample,orgin and packing date

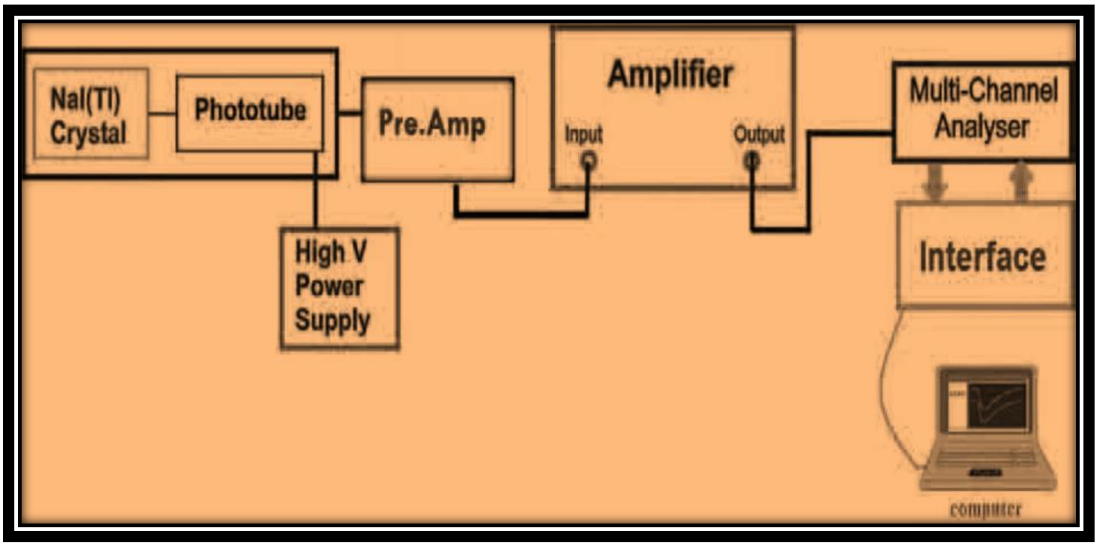
Sample code	Names. Sample	Origin	Packing date
F_1	Alkhir	Turkey	06/2021
F_2	Zehra	Turkey	O9/2021
F_3	Tak un	Turkey	02/2021
F_4	Zer	Turkey	09/2021
F_5	Bashan	Turkey	07/2021
F_6	Nawras	Turkey	08/2021
F_7	Iran	Iran	08/2021
F_8	Alt unsa	Turkey	06/2021
F_9	AL barkat	Iran	08/2021
F_{10}	Al saff	Turkey	07/2021
F_{11}	Gold	Turkey	04/2021

3.3 Preparations of Samples

The sample must be moisture-free to measure the radioactivity of samples, because the measurement of qualitative effectiveness depends on the weight of the model. To get rid of this moisture, the samples were dried and placed in the oven for a certain time depending on the type of sample, the temperature should be raised slowly until the maximum temperature was to 450 ℃, temperatures greater than 450C° may lead to the loss of radionuclides [73].After obtaining moisture-free samples, the samples were milled and sifted using a 1 mm (sieve) hole-hole clip to obtain homogeneous samples, then each sample was weighed, placed in a box and left at least a month to reach the radiation balance and, upon measurement, the sample was placed in the device's Marinelli Beaker.

3.4 Nuclear Detection and Analysis System

The natural radioactivity of gamma-emitting nuclides was measured on the basis of the high penetration force of gamma rays in materials using the electronic counting and analysis system used to detect nuclear radiation from the thallium-infused sodium iodide detector system (3"×3") NaI(Tl) ORTEC equipped with a multi-channel analysis (ORTEC-Digi Base) with 1024 channels connecting to a device known as an analog-to-digital converter that assists in converting a next pulse into binary values. In-vitro nuclear measurements and analyses are performed by the computer software MAESTRO-32, where Connect system components as in the figure (3.2).

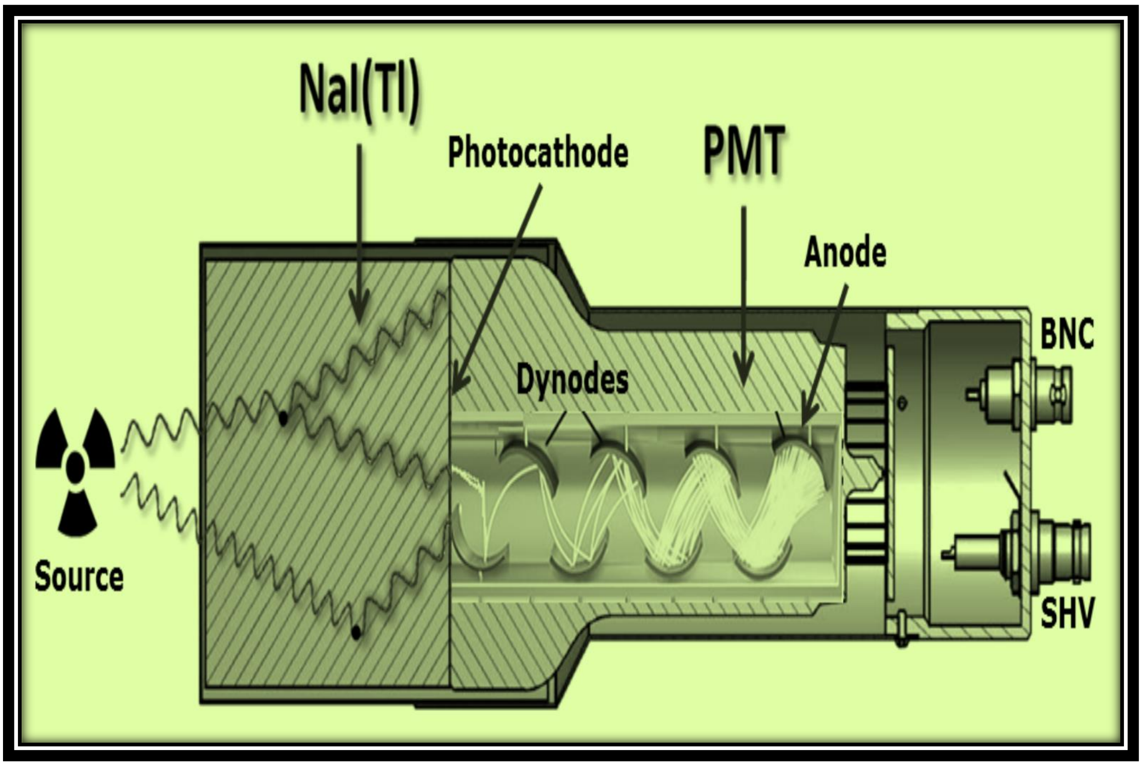


Figure(3.2): Sodium Iodide Detector System active with NaI(Tl) (3"×3") [73].

3.5 NaI(TI) Detector

The scintillator detector consists of two main parts, the Scintillator matter and the photon multiplier. As shown in Figure (3.3), the scintillator material is characterized by the production of flash (photon) when absorbed by gamma rays and photon is usually produced by removing the irritability of the material after absorbing the gamma rays.

The resulting photon in the crystal when it falls on the photo cathode produces an electron, and then the dynodes double the number of electrons. The pulse from the photo-multiplier anode is an indicator of the ionizing radiation that interacted with the crystal[74,75]



Figure(3.3) A diagram of the sodium iodide detector infused with NaI (Tl) [76].

3.5.1 Scintillation Material

NaI (Tl) is the most commonly used crystal in the detection of gamma radiation and is produced in the form of mono crystals and is high density (3.67×10^3 kg/m^3), so gamma rays will interact with the area of the section is high enough, and the work of this material depends on the properties of some solid crystals that can show the energy resulting from ionization or irritability in the form of sparkling radiation as it is called the emission of visible light or ultraviolet fluorescence [59,76].

3.5.2 Photomultiplier tube

The light from the scintillator crystal must be measured and converted into an electrical signal, this is done through the photo optical multiplier tube (PMT) as in figure (3.4) the optical multiplier tube consists of photo cathode which emits electrons when the foot falls, the nuclei generated in the flashing crystal and the accumulation of electrostatic electrons so that they fall on the first diode and because of the collision a number of secondary electrons are released to the second dynodes the number of electrons double again and thus continues to double electrons until the anode reaches on a pulse augmentation [77].

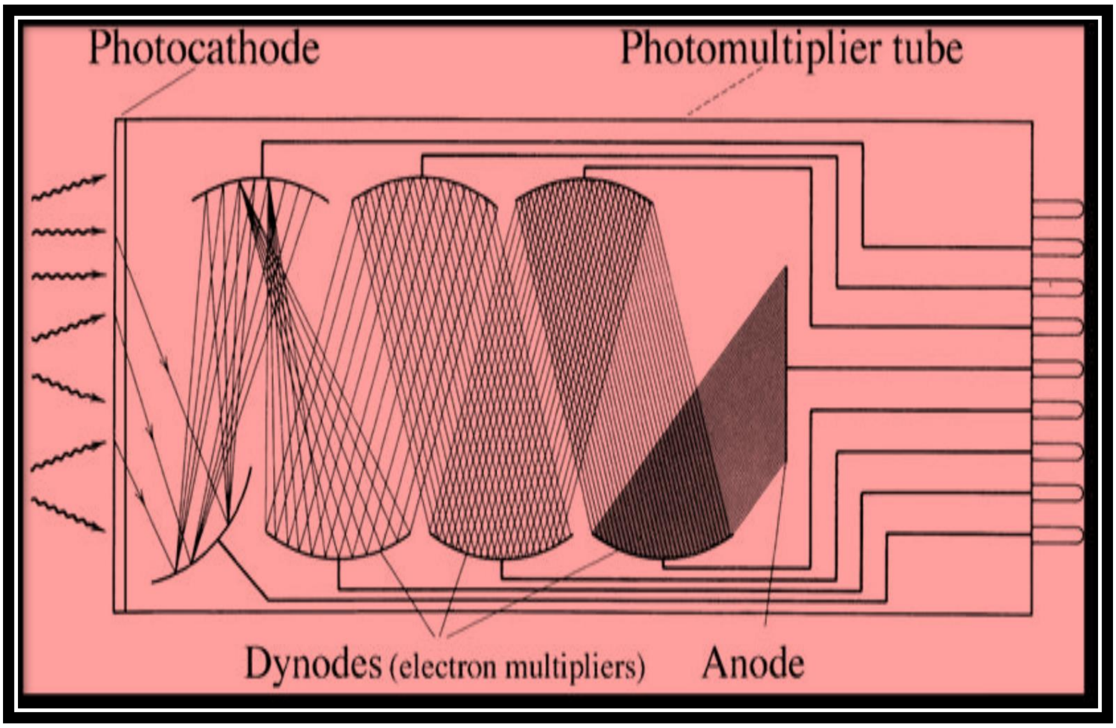


Figure (3.4): Doubling electrons during the dynodes[75].

3.5.3 Preamplifier

It is an electronic device that receives the linear charge coming from the detector and converts into a current pulse and then to the pulse of its efforts, and the latter swells to the level that can be fed to the main amplifier without deformation in its capacity. It also works basically to form the pulse to distinguish it from electronic noise as the correct modulation leads to reduced noise and improved pulse shape, leading to a higher pulse-to-noise ratio, thereby improving the ability to analyze energy.

It also performs another function, namely, the coordination of resistance between the detector and the electronic circuit that connects after it, which is the main amplifier [75]. It provides an initial amplification of the pulse as it connects very close to the detector to avoid attenuation of the pulse when it moves into the conductive wires.

3.5.4 Main Amplifier

The main amplifier enlarges the electronic pulses coming out of the primary amplifier after forming them and reaches a level that can be analyzed by a multi-channel analyzer to improves the pulse as well as shaping and filtering the noise coming in with the signal, as the signal amplification is directly proportional to the pulse capacity entering . It is part of the multi-channel analysis that is located within it. The main amplifier provides a direct linear relationship between the pulse capacity coming out to the pulse capacity, entering the so-called (Gain) [59,75].

3.5.5. High voltage power supply

Featuring high voltages the amount of reagent (0-2000 volts) and the processing of voltage spikes (essential for the work) that is required. The voltages utilized in this investigation are 775 volts, which is within the stability range of the detector's working voltage [58].

3.5.6 Multichannel Analyzer

The purpose of MCA is to convert pulse capacity into an equivalent digital number, as a multichannel analysis(MCA)records and processes pulses coming out of the main amplifier according to its capacity and that each volume called the Channel and that the pulse capacity is proportional to the energy of the photon falling on the detector, and that each pulse of these pulses is stored in a particular channel according to its capacity, i.e. the distribution of pulses in the channels is the distribution of the power of the dropped photon on the detector, finally obtain a spectrum of gamma rays[74]. The type of multi-channel analysis used in the study is (ORTEC-Digit Base).

3.5.7 Shielding

The detector and holder are covered with a cylinder-shaped shield of 20cm surrounding the crystal with a cover of 22cm diameter and 5cm thick to minimize the radiation background and the other part is the bottom that forms the base of the detector [75].

Figure (3.5): Shielding chamber and detector location inside the shield [75].

3.6 Configuration of the measurement system

Some measurements were made for the purpose of preparing the system for use, which it as fallowing:

3.6.1 Energy Calibration

The energy calibration process is intended to locate the dropped photon energy of each channel using standard sources containing well-known peaks that, when selecting these sources for calibration purposes, are taken into account to cover a wide range of elements' energies, the model to be detected [51,76].

For the energy calibration, the following standard sources used (^{22}Na, ^{137}Cs, ^{60}Co).Table (3.4) shows the energy of each of the radioactive sources used and the location of the summit accompanying each energy, while Figure (3.6) represents the relationship between the energy of the standard sources and the channel number.

Table (3.4): Energy and channel number for standard sources used for calibration

Isotope	Energy(kev)	Channel number
^{22}**Na**	511.006	77
^{137}**Cs**	661.6	98
^{60}**Co**	1173.228	169
^{22}**Na**	1274.5	184
^{60}**Co**	1332.494	189

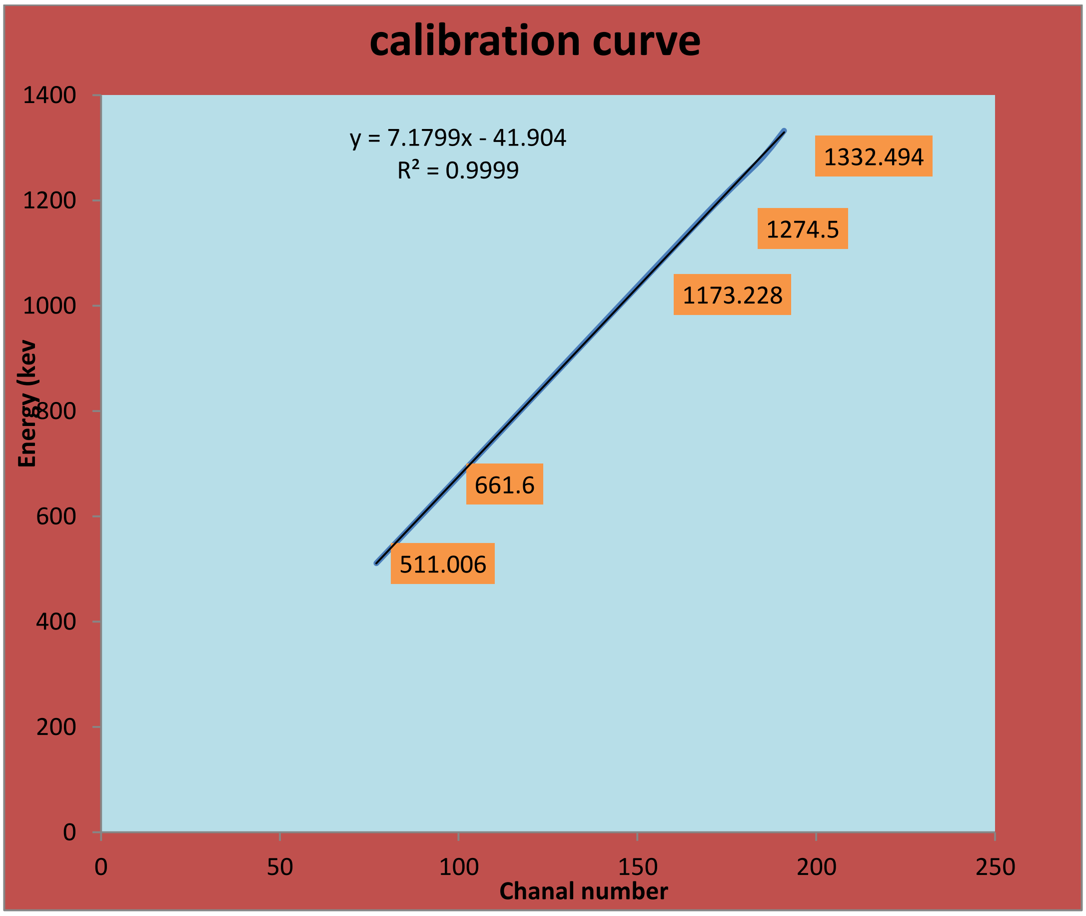


Figure (3.6): Energy calibration curve of 3"×3" NaI (Tl) detector

From figure (3.6) it was found that the relationship between energy and channel number is linear and according to the following equation:

$$E=7.1799x-41.904 \tag{3.1}$$

E : Energy

X : (Ch. No.) Channel Number

3.6.2 Efficiency Calibration

The detector's efficiency (ε) is defined as the ratio between the number of pulses recorded by detector and the number of gamma photons emitted by radioactive source, and is determined using the following equation[78].

$$\varepsilon = \frac{N}{A \times I\gamma \times t} \times 100\% \tag{3.2}$$

N: The net counting rate (the area under the photopeak after subtracted the radiation background).

t: Measurement time per second.

Iγ: Percentage of the intensity of gamma rays emitted per radioactive source energy.

A: The final radioactivity (effectiveness) of the Bq unit of the radioactive source at time t that is calculated through the equation (2.14) [78] .

To calibrate the efficiency of the NaI(Tl), standard sources with known energies were used, the decay equation (2.14) used to measure the final radioactivity of radioactive sources, the radioactivity recorded by the detector was measured for each energy of radioactive sources and for a period (500 Sec) then the efficiency calculation came through equation (3.2) and table (3.5) indicating this.

Table (3.5): Standard sources with energies known and efficiency

N	Isotopes	Energy(kev)	Efficiency%
1	^{22}Na	511	0.28
2	^{137}Cs	661.6	0.2
3	^{60}Co	1173.24	0.056
4	^{22}Na	1274.5	0.043
5	^{60}Co	1332.5	0.038

The efficiency curve, which represents the relationship between efficiency and energy, was drawn for the standard sources used and described in the form (3.7):

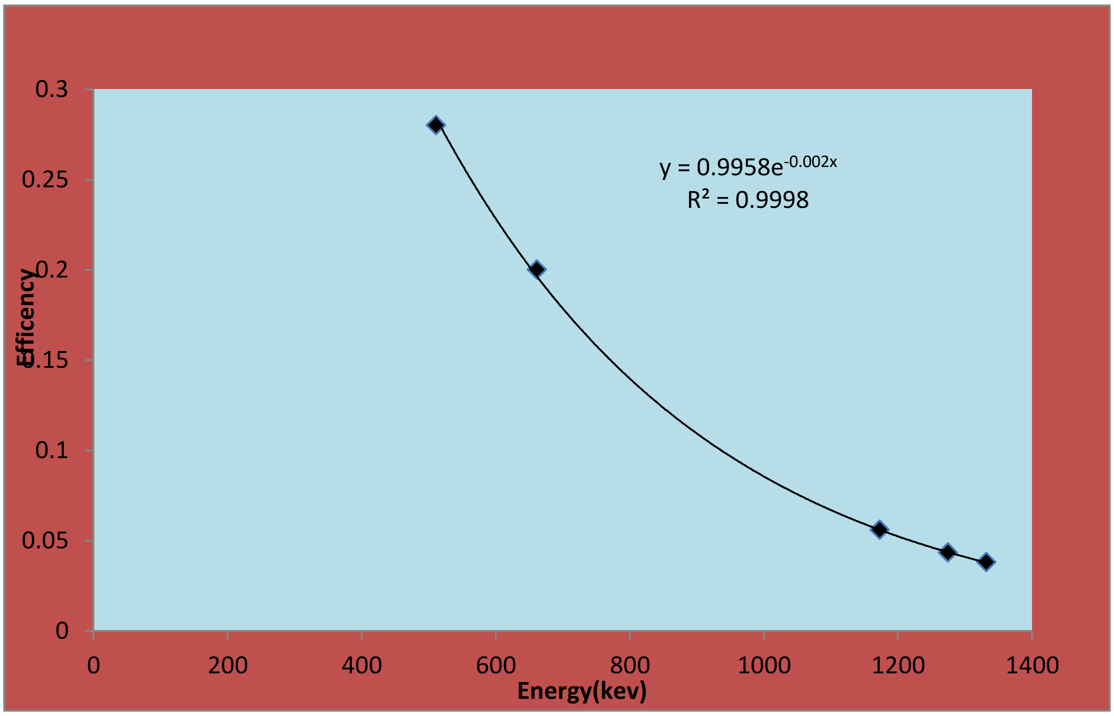


Figure (3.7) Relation between energy and efficiency

This curve enables us to determine the efficiency of the detector for different energies and for any radioactive source and according to the following equation:

$$\varepsilon = 0.9958\, e^{-0.002x} \qquad (3.3)$$

ε: efficiency

E: energy

As show in Figure (3.7) that the efficiency of the detector is at its highest energy value (661.6 kev) due to the total absorption of the dropped photon and the occurrence of the photoelectric phenomenon. also the gradual decline in this efficiency by increasing energy values, due to the low impact of the PV phenomenon and the appearance of the Compton effect, resulting in a lack of absorption of dropped photon energy due to dispersion [74,75].

3.7 The Energy and Detector Efficiency

Radionuclides were identified in the used food models under consideration through the PV emission peaks resulting from the dissolution of the ^{238}U, ^{232}Th and ^{40}K single samples, and the detection efficiency of radionuclides in food models was calculated through the equation (3.3) described in table (3.6).

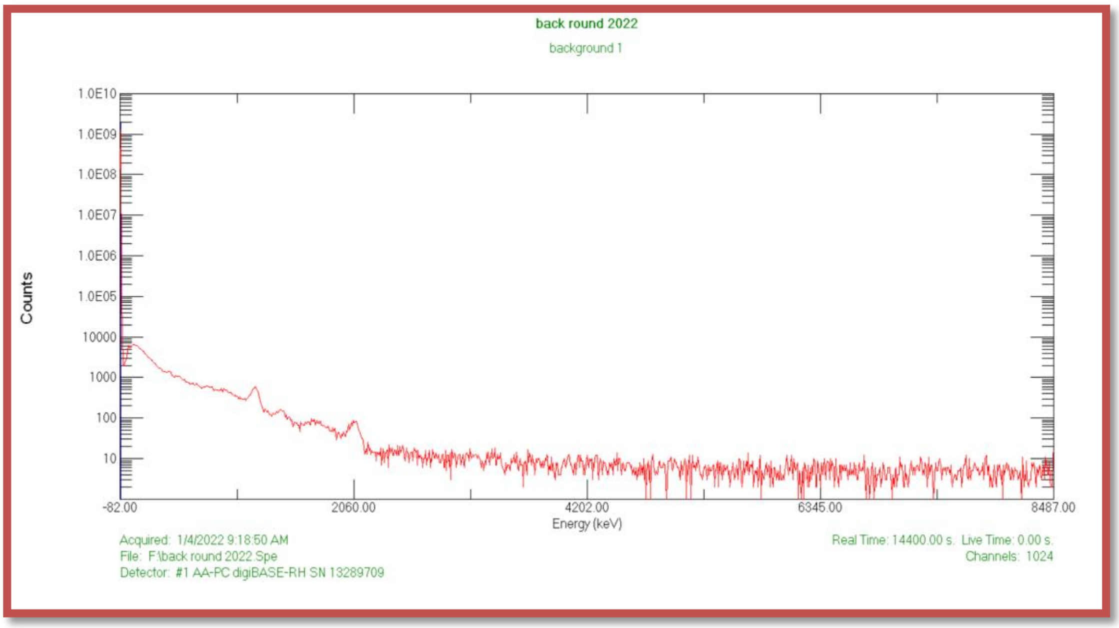
Table (3.6) :Energy and efficiency of detection of radionuclide

Isotpes and Daughter	**Energy(kev)**	**ε%**
^{40}K	1460	0.026
^{238}U (^{214}Bi)	1764	0.048
^{232}Th(^{208}Tl)	2614	0.0048

3.8 Radiation Background Measurement

As a result of cosmic radiation that continuously comes to the Earth's atmosphere and the presence of natural radiation activity in the environment, all measurement systems record radiation background signals and this backdrop changes from location to location and is dependent on the detector's quality, size, and shield's quality. This background can be increased due to the interaction of the initial gamma rays with the synthetics in the system as well as because of their interaction with the shield.

To compute the net radioactivity the samples studied, one must record the spectrum of a radiation background and subtract this from the spectrum of the each sample. The radioactive background were measured in the laboratory by inserting a one-kg Marnelli container only within detector, the same container that was used to compute the qualitative radioactivity for samples, And with a time of 14400 sec which is the same time period used to measured samples, the radiation background spectrum was recorded twice inside the research laboratory and Fig.(3.8) showing the recorded radiation background spectrum .



Figure(3.8): Radiation background spectrum

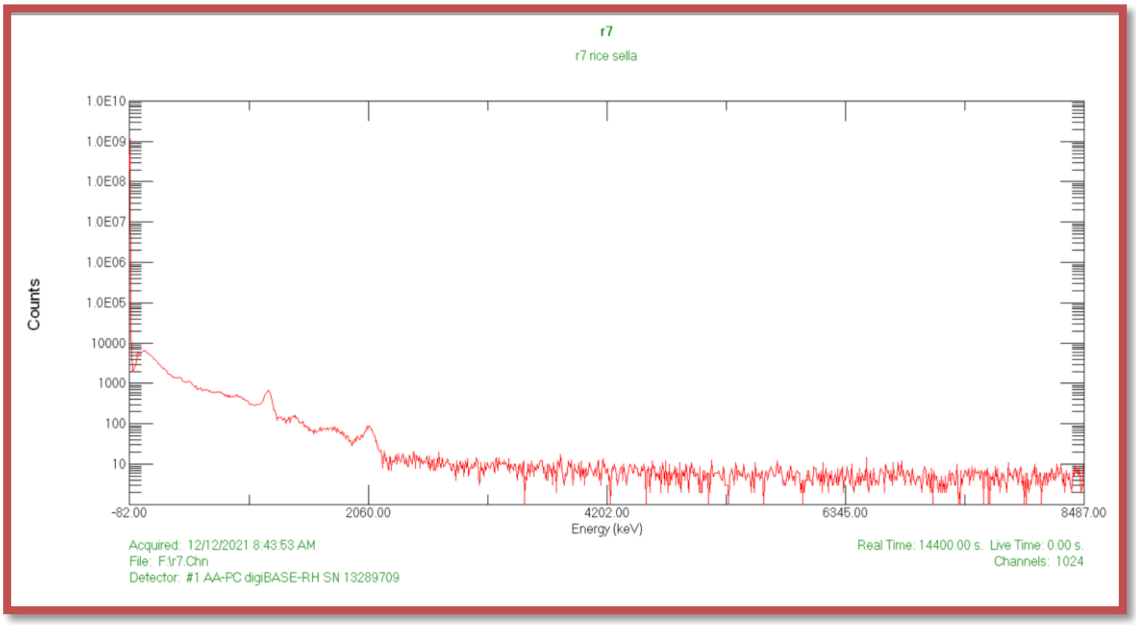


Figure (3.9): shows the sample spectrum (R_7)for 1024 channel and 14400 second time pried.

Chapter Four

Results, Discussion and Conclusions

4.1 Results and Discussion

This chapter includes the results of measured specific activity measurement in the Bq/kg unit of models of different types of food (wheat flour, rice and legumes) collected from the Iraqi local markets using the sodium iodide detector (NaI(Tl) and the time used for measurement was 14400 sec, three radioactive isotopes it the ^{238}U, ^{232}Th and ^{40}K found in nature have been diagnosed individually.

4.2 Calculating the concentration of activity

As uranium ^{238}U is balanced with its radioactive table as well as thorium ^{232}Th and its daughters, the specific activity of all elements of the two radiosurgery series is balanced, so it is possible to calculate the concentration of an element in any chain by replacing the concentration of another element, where a set of gamma rays emits a recognizable return [78]. The effectiveness of each of the ^{232}Th has been calculated by calculating the specific activity concentration of the ^{208}Tl radioactive thallium nuclei with a capacity of 2614 keV and ^{238}U by calculating the specific activity concentration of the Bismuth ^{214}Bi card. 1764 keV The concentration of radioactive potassium nuclei ^{40}K with a capacity of 1460 keV is also calculated and the quality efficiency concentrations of ^{238} U, ^{232}Th and ^{40}K have been calculated using the equation (2.17).

4.3Calculating risk transactions

The risk of ^{328}U, ^{232}Th and ^{40}K calculated from equations (2.18),(2.19)

Internal hazard index and External hazard index .

4.4 Rice

Table (4.1) shows the results of the specific activity to ^{238}U (^{214}Bi), ^{232}Th and^{40}K for different types of rice samples available in local markets in Iraq:

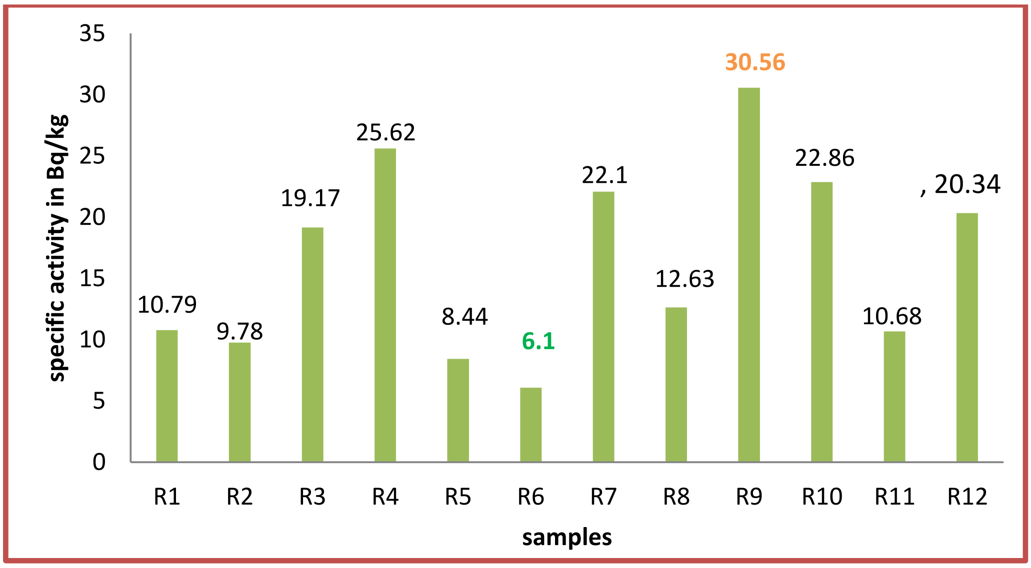
Tabie (4.1) Specific Activity of ^{40}K, ^{238}U and ^{232}Th Natural radioactivity in some types of rice

Sample.C	^{238}U	^{232}Th	^{40}k
R_1	10.79±0.4755	11.57±0.7875	346.70±25.1186
R_2	9.78±0.4258	12.91±0.8318	358.55±11.8660
R_3	19.17±0.6337	22.93±1.1085	381.86±26.3150
R_4	25.62±0.2325	24.70±1.1504	346.07±25.0955
R_5	8.44±0.4206	21.70±1.0783	409.76±27.3075
R_6	6.10±0.3575	25.07±1.1591	356.13±25.4578
R_7	22.10±0.6805	25.98±1.8005	411.93±27.3075
R_8	12.63±0.5128	16.02±0.9265	358.68±25.5487
R_9	30.56±0.800	17.95±0.9807	405.68±27.1713
R_{10}	22.86±0.6920	21.80±1.0810	430.01±28.0115
R_{11}	10.68±0.4508	16.50±0.9403	374.17±26.2116
R_{12}	20.34±0.6528	25.77±1.1751	455.91±28.9470
AV	16.58±0.5278	20.24±1.0849	388.870±23.0914

And from the table above we get the following:

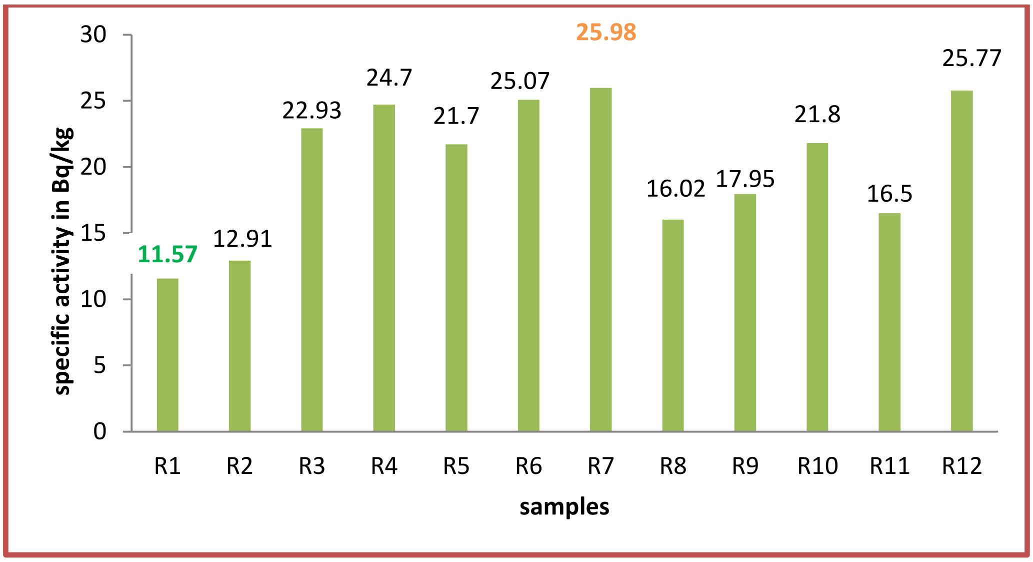
The highest value of the specific activity was ^{238}U, (30.56±0.800) Bq/kg in the sample (R9) Rice Bashan production India, and the lowest value were (6.10±0.3575) Bq/kg in the sample (R_6) Rice Thailand produced

Thailand, the average of these values was (16.58±0.527) Bq/kg as in the figure(4.1).



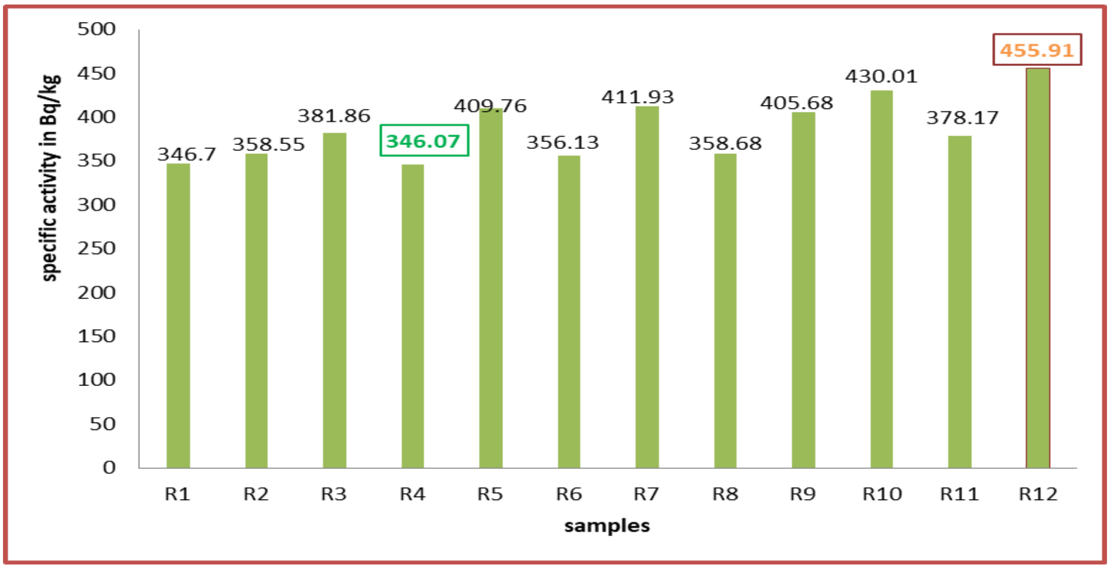
Figure(4.1):Specific activity of ^{238} U for different types of rice

For ^{232}Th, the highest value of specific activity (25.98±1.8005) Bq/kg was in the sample (R_7) and the lowest value was (R_1) (11.57±0.7875) Bq/kg in the sample Rice Joker Production India, the average of these values was (20.24±1.0849) Bq/kg as in the figure(4.2)



Figure(4.2):Specific activity of ^{232}Th for different types of rice

The highest value of the ^{40}K specific activity was (455.91±28.947) Bq/kg in the R_{12} sample of India's production Mahmood rice and the lowest value was (349.07±25.0955) Bq/kg in the sample (R_4) Elegant Rice production of India and the average of these values was (388.870±23.0914) Bq/kg as in the figure(4.3).



Figure(4.3):Specific activity of ^{40}K for different types of rice

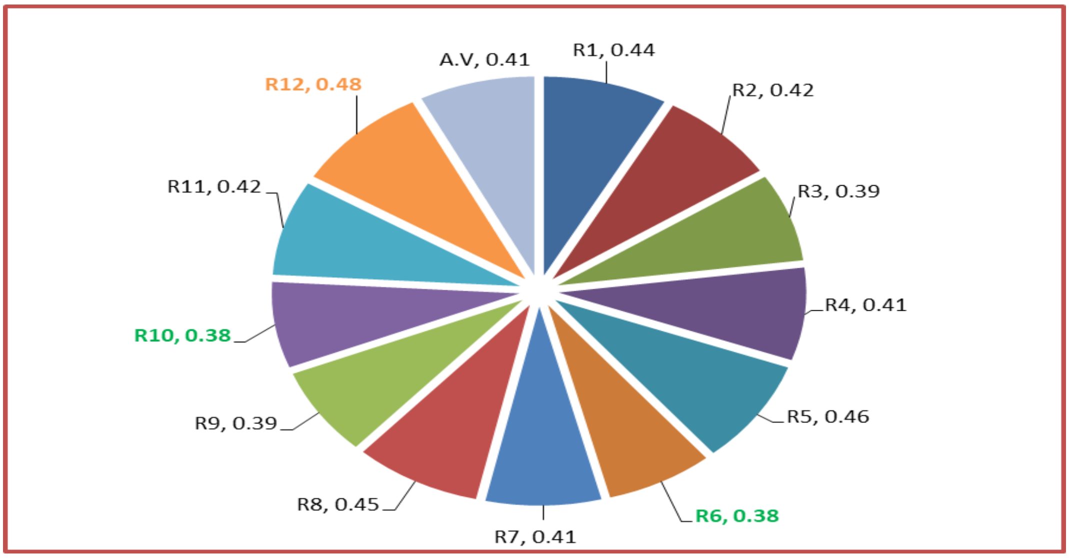
while table (4.2) shows the internal risk factors, external risk factors and the figure. (4.4) and (4.5) represent the internal risk factor and the external risk factors of rice sample:

Table (4.2) Internal risk factors and external risk factors for rice samples

Sample. Code	H_{in}	H_{ex}
R_1	0.44	0.22
R_2	0.42	0.21
R_3	0.39	0.19
R_4	0.41	0.20
R_5	0.46	0.24
R_6	0.38	0.19
R_7	0.41	0.21
R_8	0.45	0.23
R_9	0.39	0.20
R_{10}	0.38	0.19
R_{11}	0.42	0.22
R_{12}	0.48	0.25
A.V	0.419	0.2125

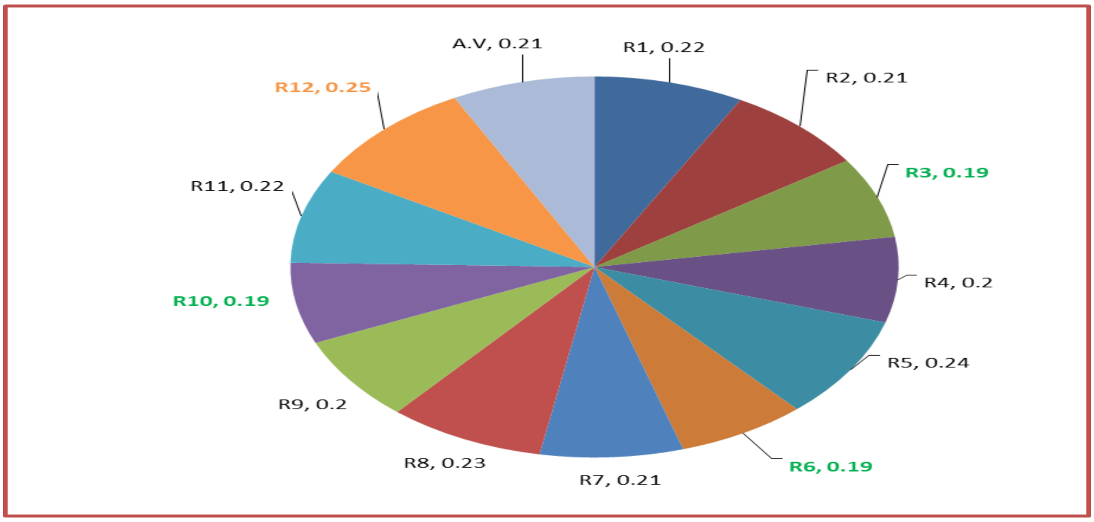
And from the table above we get the following:

the highest value of the internal risk factor was (0.48) in the sample Mahmoud Rice (R_{12}) production India , the lowest value was (0.38) in the sample(R_6), (R_{10}) production Thailand, India and the was average of these values (0.419) as in the figure(4.4).



Figure(4.4):The internal hazard index of different rice types

The highest value of the external risk factor was(0.25) in the sample (R_{12}) production India , the lowest value was (0.19) in the sample (R_3,R_6,R_{10}) production Vietnam , Thailand , and India respectively, the average of these values (0.2125) as in the figure(4.5). The internal risk factor and the external risk factors of all models were within the globally permitted limit.



Figure(4.5):The External hazard index of different rice types

4.5 Wheat flour group

The Specific activity of each of the ^{238}U, ^{232}Th.^{40}K for different types of wheat flour samples was calculated as shown in the table (4.3). The

demonstrates the Specific activity of the wheat flour samples examined. The

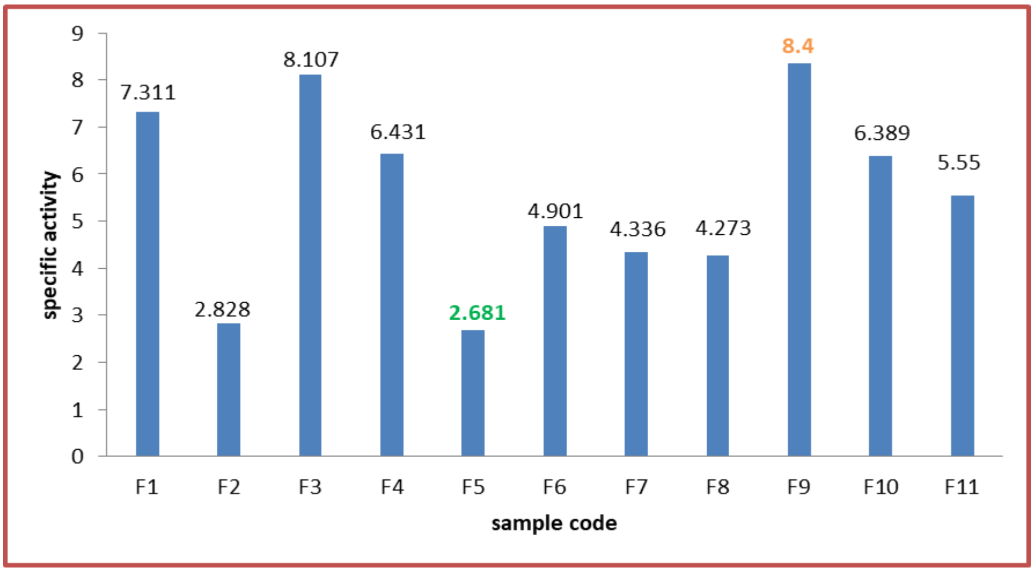
results show that:

Tabie (4.3)Specific Activity of 40K, 238 U and 232Th Natural radioactivity in flour samples flour samples

S.c	^{238}U	^{232}Th	^{40}K
F_1	7.311±0.391	18.754±1.002	101.18±1.356
F_2	2.828±0.243	8.841±0.688	108.13±1.402
F_3	8.107±0.421	15.378±0.907	117.59±1.462
F_4	6.431±0.335	26.417±1.189	112.64±1.431
F_5	2.681±0.237	24.916±1.155	132.11±1.550
F_6	4.901±0.320	27.274±1.165	114.61±1.444
F_7	4.336±0.301	28.826±1.242	168.69±1.752
F_8	4.273±0.299	24.916±1.155	122.29±1.491
F_9	8.400±0.419	18.379±0.992	123.09±1.496
F_{10}	6.389±0.365	24.863±1.154	124.98±1.508
F_{11}	5.55±0.3410	17.03±0.9555	98.92±1.3410
AV	5.564±0.309	21.417±1.054	120.384±1.384

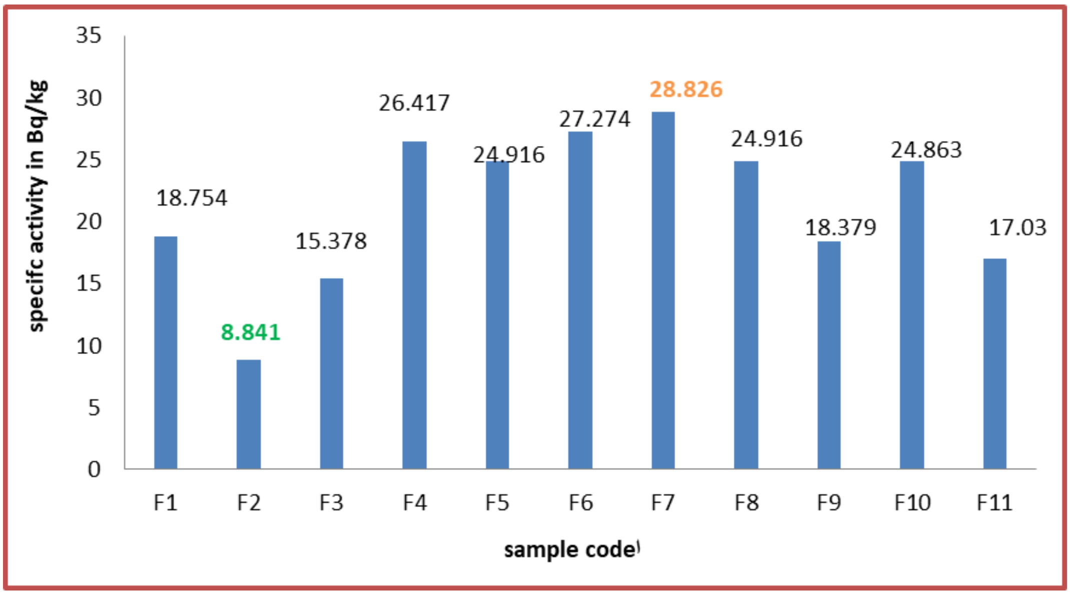
And from the table above we get the following:

The highest value of the Specific activity ^{238}U (^{214}Bi) was (8.400±0.419) Bq/kg in the sample (F_9) Flour AL barkat Production Iran, the lowest value was(2.681±0.237 Bq/kg) in the sample (F_5) Bashan flour produced by Turkey and the average of these values was(5.564±0.309) Bq/kg as in the figure(4.6)



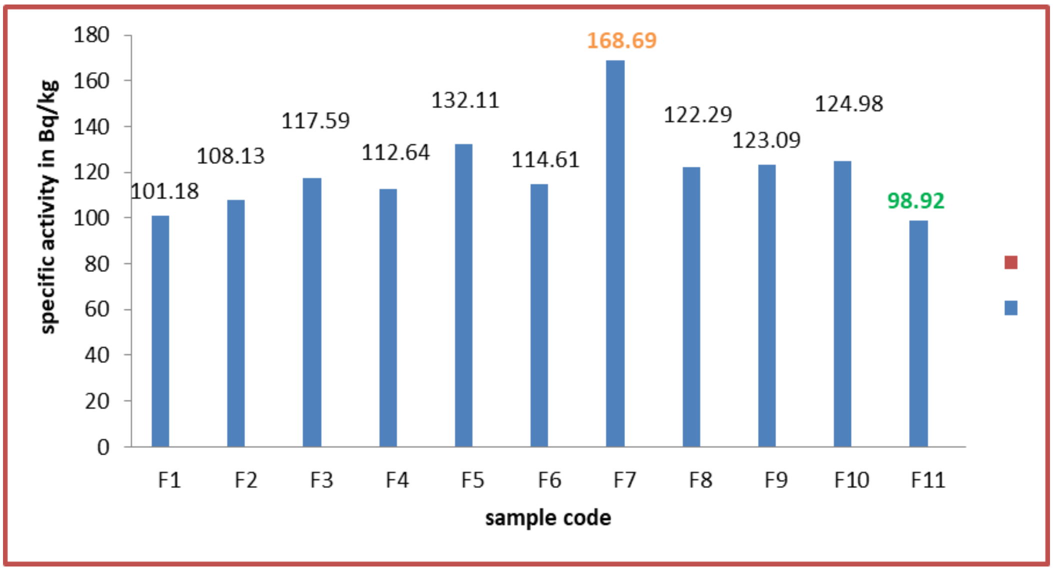
Figure(4.6): Specific activity of ^{238}U for different types of flour

For ^{232}Th, the highest value of Specific activity (28.826±1.242) Bq/kg was in the sample (F_7) luxury flour produced by Kuwait and the lowest value was(8.841±0.688) Bq/kg in the sample (F_2) Zahra flour produced by Turkey and the average of these values was (21.417±1.054) Bq/kg as in the figure (4.7



Figure(4.7):Specific activity of ^{232}Th for different types of flour

The highest value of the Specific activity of ^{40}K was (168.69±1.752) Bq/kg in the sample (F_7) Iran flour Produced by Iran and the lowest value was (98.92±1.3410) Bq/kg in the sample (F_{11}) gold flour produced by Turkey and the average of these values was (120.384±1.384) Bq/kg as in the figure (4.8)



Figure(4.8):Specific activity of ^{40}K for different types of flour

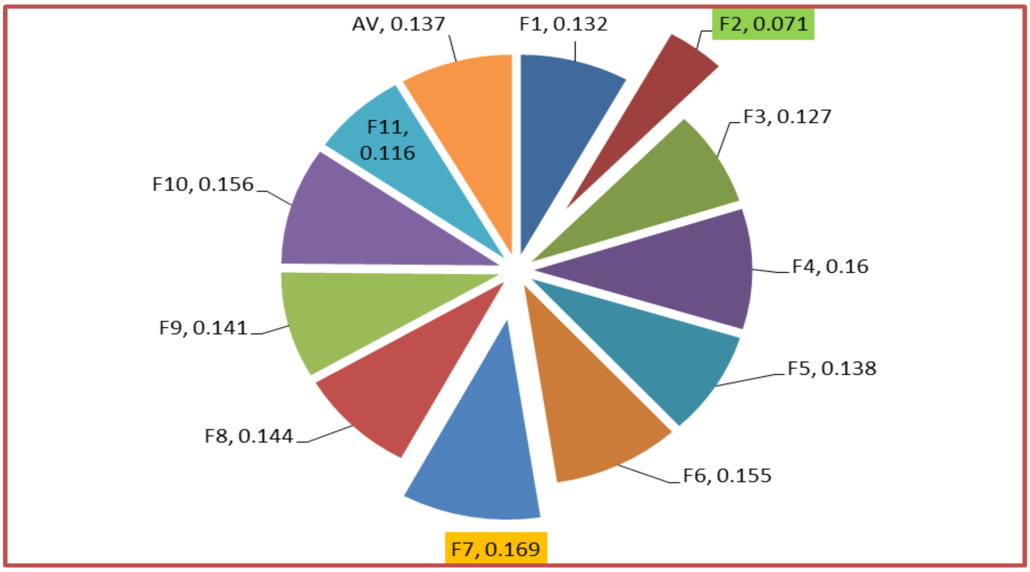
The values of qualitative radioactivity of ^{238}U, ^{232}Th and ^{40}K were found to have been distributed at varying proportions for wheat flour samples within the globally permitted range.

Table (4.4) shows the results internal risk factors and the external risk factors for flour samples and through the results show that :

Table (4-4) Internal risk factors and external risk factors for flour samples

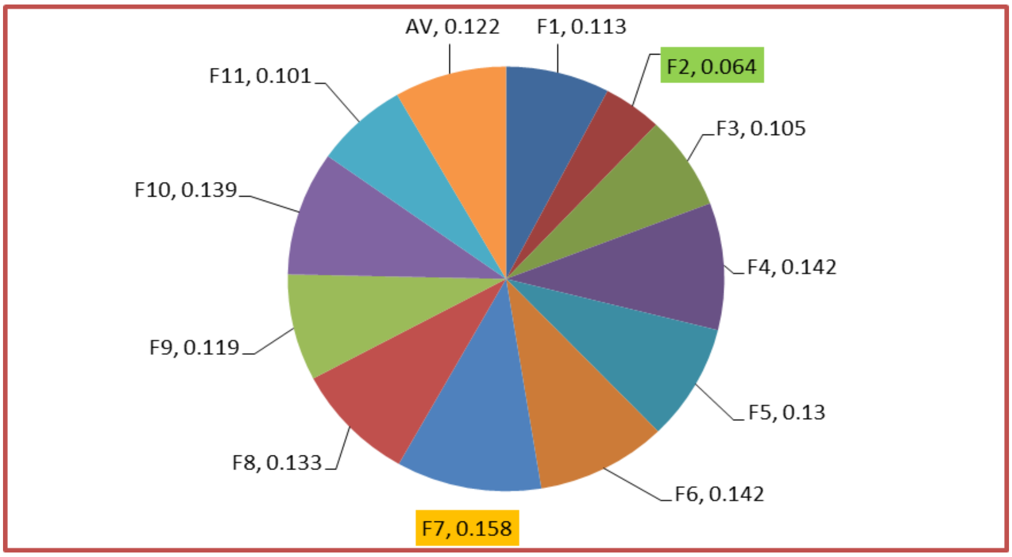
S.c	H_{in}	H_{ex}
F_1	0.132	0.113
F_2	0.071	0.064
F_3	0.127	0.105
F_4	0.160	0.142
F_5	0.138	0.130
F_6	0.155	0.142
F_7	0.169	0.158
F_8	0.144	0.133
F_9	0.141	0.119
F_{10}	0.156	0.139
F_{11}	0.116	0.101
A.V	0.137	0.122

The highest value of the internal risk factor was 0.169 in the sample (F_7) safa flour produced by Iran, The lowest value was (0.071) in the sample (F_2) Zahra flour, the average of these values was (0.137) as in the figure (4.9)



Figure(4.9): Internal hazard index of different types of flour

The highest value of the external risk factor was(0.158) in the model (F_7) production Iran , the lowest value was (0.064) in the sample (F_2) Zehra production Turkey and the average of these values was (0.122) as in the figure (4.10).The internal risk factor and the external risk factors of all samples were within the globally permitted limit



Figure(4.10) External hazard index of different types of flour

4.6 Dry legumes

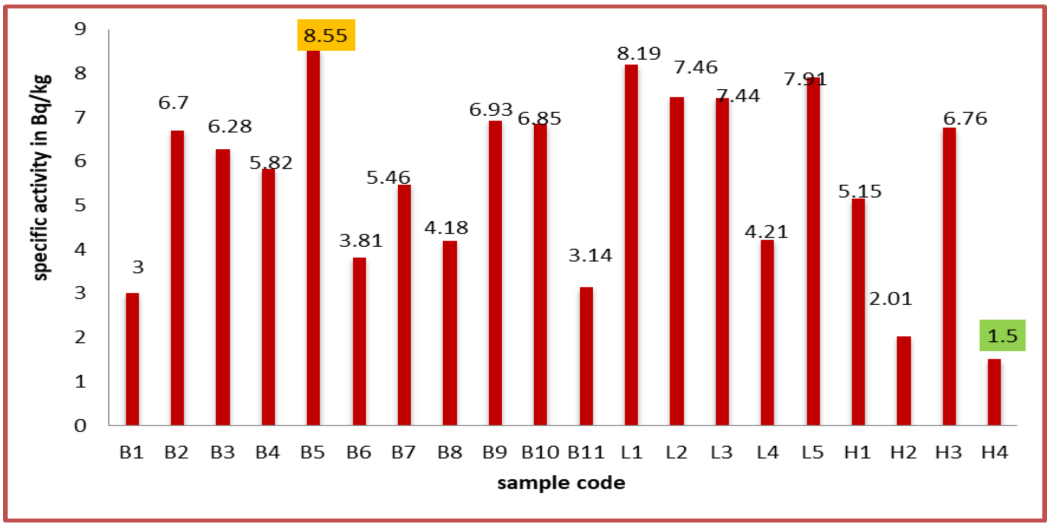
Table (4.5) shows the results of the Specific activity of ^{238}U,^{232}Th,^{40}K for different types of dry legumes samples available in Iraqi city markets, while table(4.6) shows internal hazard index and external risk factors for each legume sample under consideration

Tabie (4.5): Specific Activity of ^{40}K, ^{238}U and ^{232}Th Natural radioactivity in sometypes of legumes.

S.c	^{238}U	^{232}Th	^{40}K
B_1	3.00±0.250	28.45±1.2347	406.10±2.7185
B_2	6.70±0.3748	19.82±1.0307	424.08±2.7780
B_3	6.28±0.3629	20.89±1.0581	426.0±2.7843
B_4	5.82±0.3494	17.68±0.9733	397.77±2.6904
B_5	8.55±0.4232	18.00±0.9822	407.52±2.7232
B_6	3.81±0.2826	17.62±0.9719	438.35±2.8240
B_7	5.46±0.3384	30.00±1.2680	378.63±2.6240
B_8	4.18±0.2962	24.97±1.1567	403.60±2.7100
B_9	6.93±0.3811	25.88±0.1642	396.97±2.6870
B_{10}	6.85±0.3788	15.48±0.9109	330.88±2.4530
B_{11}	3.14±0.2565	28.45±1.2347	289.64±2.2950
L_1	8.19±0.4143	19.45±1.0209	311.91±2.3824
L_2	7.46±0.3953	20.68±1.0527	322.57±2.4228
L_3	7.44±0.3948	14.19±0.8722	296.55±2.3230
L_4	4.21±0.2969	28.77±1.2417	391.56±2.4110
L_5	7.91±0.4072	22.29±1.0929	150.93±1.6570
H_1	5.15±0.3285	18.969±1.0081	298.23±2.329
H_1	5.15±0.3285	18.969±1.0081	298.23±2.329

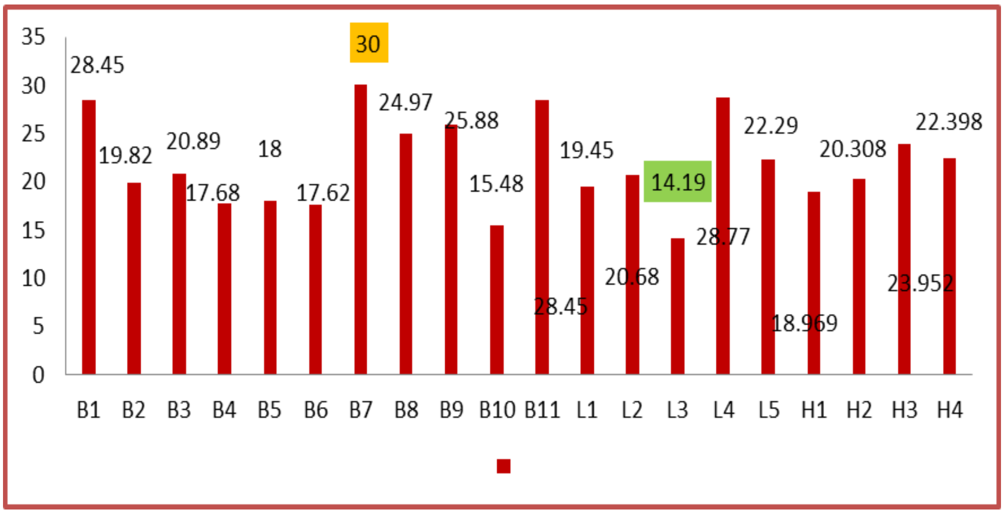
H_2	2.01±0.2052	20.308±1.0307	25.91±0.686
H_3	6.76±0.3764	23.952±1.1329	274.97±2.236
H_4	1.50±0.1777	22.398±1.1727	295.97±2.230
AV	5.567±0.3158	21.912±0.9804	333.857±4.1982

The highest value of the Specific activity of ^{238}U was (8.55±0.4232) Bq/kg in sample (B_5) of Russia's production Cowpeas and the lowest value was(1.50±0.1777) Bq/kg in sample (H_4) white beans produced by Mexico and the average of these values was(5.567±0.3158) Bq/kg) as in the figure (4.11)



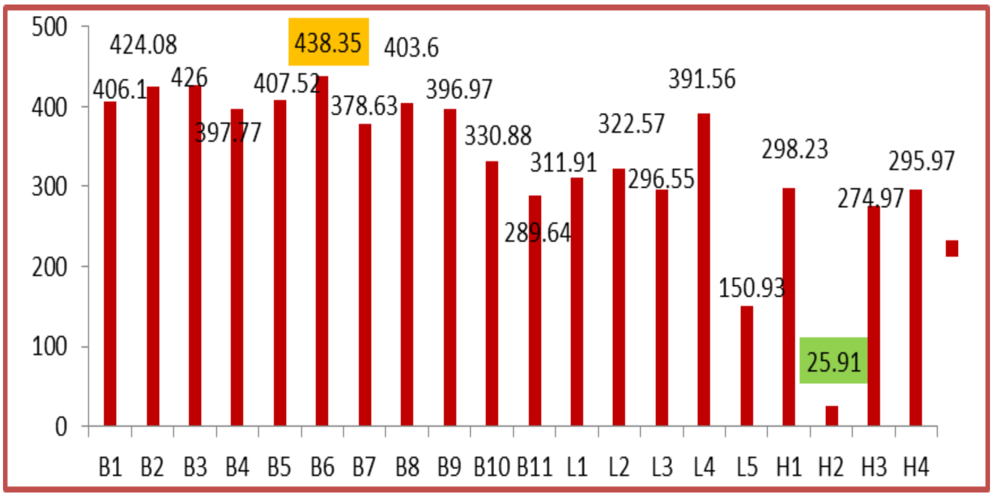
Figure(4.11): Specific activity of $^{238}U$for different types of legumes

As for ^{232}Th, the highest value of Specific activity (30.00±1.2680) Bq/kg was in the B_7 sample of produced Madagascar, the lowest value was (14.19±0.8722) Bq/kg in the L_3 white beans sample produced by Egypt and the average of these values was(21.912±0.9804) Bq/kg as in the figure (4.12).



Figure(4.12): Specific activity of ^{232}Th for different types of legumes

The highest value of the Specific activity of ^{40}K was (438.35±2.8240) Bq/kg in the B_6 sample) white beans (Tuna Sa) produced by Turkey, the lowest value for sample (H_2) was (25.91±0.686) Bq/kg in the Argentine production pea model and the average of these values was (333.857±4.1982) Bq/kg as in the figure(4.13)



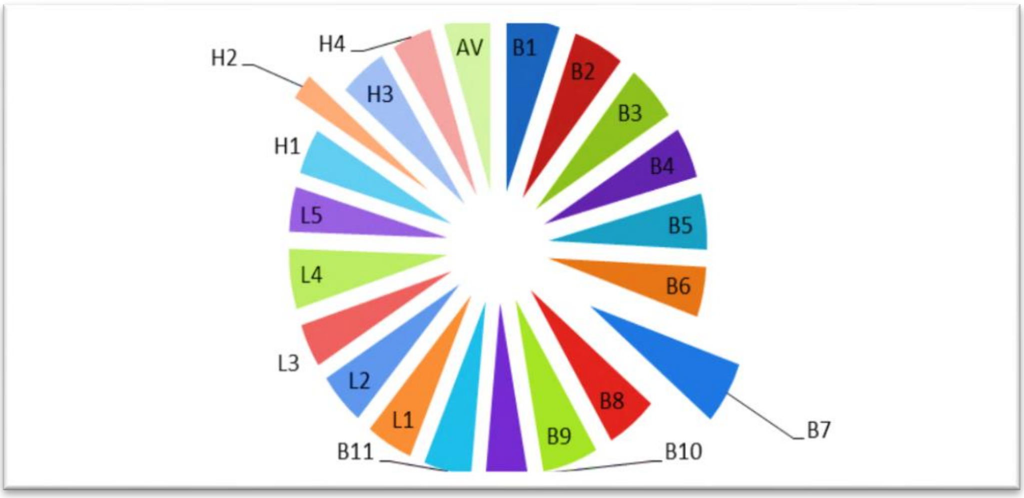
Figure(4.13): Specific activity of ^{40} K for different types of legumes

Table. (4.6): Internal risk factors and external risk factors for legumes samples

S	H_{in}	H_{ex}
B_1	0.210	0.202
B_2	0.200	0.182
B_3	0.203	0.186
B_4	0.182	0.166
B_5	0.200	0.177
B_6	0.179	0.169
B_7	0.224	0.209
B_8	0.202	0.191
B_9	0.219	0.201
B_{10}	0.165	0.147
B_{11}	0.187	0.178
L_1	0.184	0.162
L_2	0.187	0.167
L_3	0.156	0.136
L_4	0.2152	0.203
L_5	0.1601	0.138
H_1	0.163	0.149
H_2	0.094	0.089
H_3	0.186	0.167
H_4	0.156	0.152
AV	0.183	0.1685

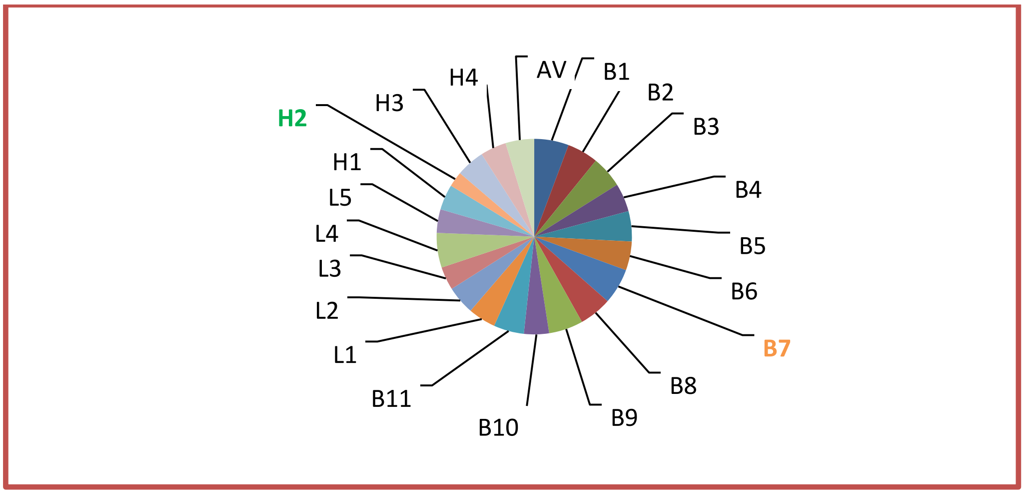
And from the table above we get the following:

The highest value of the internal risk factor was 0.224 in the sample (B_7) Alt Unsa produced by Madagascar, the lowest value was (0.094) in the sample (H_2) Crushed produced Ukraine. Table(4.4), the average of these values was (0.183) as in the figure (4.14)



Figure(4.14): Internal hazard index of different legumes type

The highest value of the external risk factor was(0.209) in the sample (B_7) Alt Unsa produced by Madagascar, the lowest value was (0.089) in the sample (H_2) production Ukraine and the average of these values was (0.1685) as in the Figure (4.15)



Figure(4.15): External hazard index of different legumes type

4.7 Conclusions

Through the results of the food samples (rice, legumes, wheat flour) the following was reached:

1. We conclude from this that the average of radiation activity in imported food in the current study were within the limits allowed globally, according to the Atomic Energy Organization (UNSCEAR) and the International Committee for radiation protection, which were safe for human consumption and did not pose a radiation hazard when eaten as food.

2. It was found that all the values of internal risk factors and external risk factors for foodstuffs, including legumes, rice and wheat flour, were within the internationally permitted limits.

3. It was found that the concentration of potassium radiation activity in rice and legumes samples was higher than that of wheat flour because radioactivity depends on the type of food, the type of soil and fertilizer used.

4. The values of potassium radiation activity were found to be the highest assessor of uranium and thorium radiation activity Because of the abundance of potassium in nature more than them

5. There are many reasons that lead to different values of potassium, thorium and uranium, including the nature of the earth, the type of fertilizer used, and environmental conditions.

4. 8 Recommendations and Future works

1. Use of various measurement techniques such as high-purity germanium detector system, solid state detectors and Conduct research and studies to

assess levels of natural radiation activity in other nutrients such as fruits, vegetables, juices and soft drinks.

2.Work to provide scientific and research institutions with modern and adequate systems for environmental studies of radiation activity.

3. Increase the number of samples and use different brands for different food items available on the market.

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الخلاصة

تضمنت الدراسة الحالية تقييم مستويات النشاط الاشعاعي الطبيعي لبعض النوى في المواد الغذائية المستوردة والتي شملت 43 عينة تم جمعها من الأسواق العراقية وقد تم إجراء القياسات باستخدام كاشف يوديد الصوديوم المطعم بالثاليوم NaI(Tl) الذي ابعاده هي ("3×"3) لقياس الفعالية النوعية لنوى اليورانيوم والثوريوم والبوتاسيوم وبزمن قياس مقداره اربع ساعات وقد وجد ان معدل قيم الفعالية النوعية لليورانيوم ^{238}U, والثوريوم ^{232}Th, والبوتاسيوم ^{40}K على التوالي في عينات الرز هو(0.52 ±16.85) , (20.24±1.08), (388.87±23.09) Bq/ kg.في حين كانت قيم متوسط الفعالية النوعية لعينات دقيق القمح هي (5.564±0.30) ,(21.417±1.05), Bq/ kg(120.38±1.38) . واخيرا كانت قيم الفعالية النوعية في البقوليات كما يلي (5.67±0.31) ،(21.19±0.98),(333.85 ±4.19) Bq / kg .

تم تحليل العينات المدروسة ومقارنتها مع المعدل العالمي والحدود المسموح بها التي وضعتها الوكالة العلمية الدولية (UNSCEAR) ومن خلال مقارنة النتائج مع القيم العالمية ,^{232}Th=45 , ^{238}U=32 , ^{40}K=412 , Bq/ kgوحسب منظمة الطاقه الذرية واللجنة الدولية للحماية من الاشعاع (ICRP)وجدت ان مستويات النشاط الاشعاعي للنماذج المدروسة في الرز وطحين القمح, والبقوليات ومعظم العينات تقع ضمن المعدلات الطبيعيه المسموح بها وانها لاتشكل خطرا اشعاعيا على الاستهلاك البشري.

كما وجدنا معامل الخطورة الداخلي لعينات الرز وطحين القمح والبقوليات على التوالي هي(0.419), (0.137) (0.183), وايضا وجدنا أن معدل معامل الخطورة الخارجي للعينات ذاتها هو(0.122 (0.212),) ,(0.168) اعتبرت هذه للعينات التي تم فحصها مسموح بها من حيث تلوث الإشعاع النووي ,ويعتبر طبيعي مقارنة بالحدود التي أوصت بها لجنة الأمم المتحدة العلمية للبحوث العلمية والاستراتيجية (UNSCEAR).

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بابل/ كلية التربيه للعلوم الصرفه

قسم الفيزياء

تقييم مستويات النشاط الاشعاعي الطبيعي في بعض منتجات الاغذية المستوردة في الاسواق العراقية

رسالة مقدمة

إلى

مجلس كلية التربية للعلوم الصرفة -جامعة بابل

وهي جزء من متطلبات نيل درجة الماجستير في الفيزياء

من قبل

حمزه عجيل مازون مرزه

بكالوريوس تربية فيزياء /الجامعة المستنصرية

1995

بإشراف

أ. د. مهند حسين عليوي

1444ه **2022م**