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## دراسة التلوث الاشعاعي للأغذية المتوفرة في بعض الأسواق العراقية وتأثيراته البيولوجية على الانسان

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**Republic of Iraq**

**Ministry of Higher Education and Scientific Research**

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**Department of Physics**



# **Study of Radioactive Contamination for Foods Available in some Iraqi Markets and their Biological Effects on Human**

A Thesis

Submitted to the Physics Department-College of Science- University of Babylon in Partial  
Fulfillment of the Requirements for the Degree of Master of Science in Physics.

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## DEDICATION

To

♣ My mother and father for their  
ever lovely encouragement.

♣ My sister for their help and  
support.

♣ To my husband and my children  
for their patience.

Zainab



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## الخلاصة

يعتبر ابتلاع النويدات المشعة في الأطعمة أحد أسباب تعرض الإنسان لجرعات الإشعاع ، فمصادر النشاط الإشعاعي في البيئة لها أصول طبيعية وبرية وخارجية وبشرية المنشأ. يمكن أن تنتقل النويدات المشعة إلى النباتات عن طريق الترسيب أو من التربة. تهدف هذه الدراسة إلى تقييم نشاط تراكيز النويدات المشعة ( $^{40}\text{K}$  و  $^{232}\text{Th}$  و  $^{238}\text{U}$ ) لستة وسبعون عينة تم اختيارها من الأطعمة (الخضار ، الخضار الورقية ، الفواكه واللحوم).

تم جمع هذه العينات من (قرية التويثة الواقعة جنوب شرق مدينة بغداد بالقرب من المفاعل النووي و مدينة الحلة و منطقة الرميلة الواقعة شمال مدينة البصرة و مدينة كربلاء) ، تم قياس أشعة جاما باستخدام كاشف يوديد الصوديوم.

بالنسبة لقرية التويثة أعلى قيمة نشاط  $^{238}\text{U}$  في الريحان هي  $3.606 \pm 0.585 \text{ Bq/Kg}$  ، لك  $^{232}\text{Th}$  في الفلفل حار  $5.984 \pm 0.710 \text{ Bq/Kg}$  و لك  $^{40}\text{K}$  في اليوسفي هي  $0.038 \pm 0.022 \text{ Bq/Kg}$  ، أقل قيمة نشاط  $^{238}\text{U}$  هي  $2757.032 \pm 27.280 \text{ Bq/Kg}$  ، لك  $^{232}\text{Th}$  تساوي  $0.063 \pm 0.031 \text{ Bq/Kg}$  و لك  $^{40}\text{K}$  هي  $36.396 \pm 2.171 \text{ Bq/Kg}$  في نوع واحد من التمور يسمى الخستاوي (باللغة العربية) .

لمدينة الحلة هي الأعلى تبلغ قيمة النشاط  $^{238}\text{U}$   $2.796 \pm 0.453 \text{ Bq/Kg}$  في فلفل حار ، و  $^{232}\text{Th}$  في الملوخية هي  $3.226 \pm 0.447 \text{ Bq/Kg}$  و لك  $^{40}\text{K}$  في الريحان هي  $825.795 \pm 25.843 \text{ Bq/Kg}$  ، وأقل قيمة نشاط  $^{238}\text{U}$  في الباذنجان هي  $0.007 \pm 0.005 \text{ Bq/Kg}$  ، من  $^{232}\text{Th}$  في النارج هي  $0.040 \pm 0.028 \text{ Bq/Kg}$  و لك  $^{40}\text{K}$  في السمك هي  $30.033 \pm 0.0617 \text{ Bq/Kg}$ .

بالنسبة لمنطقة الرميلة أعلى قيمة نشاط  $^{238}\text{U}$  هي  $2.031 \pm 0.522 \text{ Bq/Kg}$  في الباذنجان ، من  $^{232}\text{Th}$  في الملوخية هي  $10.502 \pm 0.907 \text{ Bq/Kg}$  و لك  $^{40}\text{K}$  في الملوخية هو  $697.279 \pm 21.100 \text{ Bq/Kg}$  وأقل قيمة نشاط  $^{238}\text{U}$  هي  $0.058 \pm 0.030 \text{ Bq/Kg}$  في اللوبيا ، و  $^{232}\text{Th}$  تساوي  $0.032 \pm 0.032 \text{ Bq/Kg}$  في البرتقال ، لك  $^{40}\text{K}$  تساوي  $6.896 \pm 1.625 \text{ Bq/Kg}$  في السمك.

وبالنسبة لمدينة كربلاء أعلى قيمة نشاط  $^{238}\text{U}$  هي  $2.060 \pm 0.364 \text{ Bq/Kg}$  في ملوخية ، من  $^{232}\text{Th}$  هي  $1.316 \pm 0.298 \text{ Bq/Kg}$  في نوع واحد من التمور يسمى الزهدي و لك  $^{40}\text{K}$  هو

±0.028 Bq/Kg هي  $^{238}\text{U}$  أقل قيمة نشاط في البامية.  $1014.644 \pm 27.452$  Bq/Kg في الرمان ، و  $^{232}\text{Th}$  هي  $0.094 \pm 0.039$  Bq/Kg في اللوبيا و  $^{40}\text{K}$  هي  $11.598 \pm 1.523$  Bq/Kg في الرمان.

تم استخدام برنامج الاحصاء Genstat لايجاد العلاقة بين معدلات النشاط الإشعاعي للنويدات المشعة ونسبة عدد المصابين بالسرطان في محافظة (بغداد والحلة والبصرة وكربلاء) وكانت اعلى نسبة في محافظة بغداد

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## List of Abbreviations

Symbols	Description
DU	Depleted Uranium
<sup>238</sup> U	Uranium-238
<sup>232</sup> Th	Thorium-232
<sup>40</sup> K	Potassium-40
LLW	Low Level Waste
DNA	Deoxyribonucleic Acid
U	Uranium
HYGe	Hyper Pure Germanium
NaI (TI)	Sodium Iodide doped with Thallium
IAEA	International Atomic Energy Agency
UNSCEAR	United National Scientific Committee on the Effects of Atomic Radiation
MDA	Minimum Detectable Activity
SSNTD	Soil State Nuclear Track Detector
AED	Annual Effective Dose
BDL	Below Level Detection
RNA	Ribonucleic Acid
A	Activity
AD	Absorbed Dose Rate
R <sub>a<sub>eq</sub></sub>	Radium Equivalent Activity
H <sub>in</sub>	Internal Radiation Hazaed
I <sub>y</sub>	Activity Concentration Index
Bq/Kg	Becquerel / Kilogram
nGy/h	Nano Gray/Hour
μSv/y	Microsieverts / Year
ORTEC	Oak Ridge Technical Enterprise Corporation
MCA	Multichannel Analyzer
PMT	Photo Multiplier
GPS	Global Positioning System
L.S.D	Least Significant Difference
ICRP	International Commission on Radiological Protection
IAEA	International Atomic Energy Agency
T <sub>phys</sub>	Physical Time

## **1.1 Background Radiation**

Radioactive isotopes of elements (radionuclides) are naturally presented in the environment, and that includes our bodies and our food and water. We are exposed to radiation (also known as background radiation) from these radionuclides on a daily basis. Radiation comes from space (i.e., cosmic rays) as well as from naturally-occurring radioactive materials (radionuclides) found in the soil, water and air. Radioactivity can be detected in food and water and the concentration of naturally-occurring radionuclides varies depending on several factors such as local geology, climate and agricultural practices [1].

The particles in space are 92% protons and 6% alpha particles; the remainder are heavier atomic nuclei. The galactic flux of primary cosmic rays is very large, about 100000/m<sup>2</sup>-s. about 360/mz-s, so few of the galactic particles have adequate energy to penetrate the earth's atmosphere. A second source of primary cosmic rays is the sun, with its eleven-year cycle. Terrestrial cosmic rays vary over time because of the solar cycle. Energetic cosmic rays at sea level ,at airplane altitudes [2].

The earth's atmosphere consists of about 1033 g/cm of oxygen and nitrogen, with a density which changes constantly with altitude. In cosmic ray physics, altitude is usually considered in units of g/cm<sup>2</sup> of the atmosphere above a given height. Sea level has an altitude of 1033 g/cm<sup>2</sup>, and Denver has an altitude of 852 g/cm [3].

People can also be exposed to radiation from man-made activities, including medical diagnostic intervention. Radioactivity can contaminate food after it has been discharged into the environment from industries that concentrate natural radionuclides and from civil or military nuclear operations. Whether, man-made or natural in origin, radioactive material passes through the food chain in the same way as non-radioactive material.

The degree of harm to human health depends on the type of radionuclides and the length of time people are exposed to. The amount of radiation people are exposed to varies from place to place and among individuals. Land, rivers, sea and structures in the vicinity of the power plant can become contaminated with a mixture of radionuclides generated inside the reactor, also known as “nuclear fission products”. People can therefore be exposed to radiation from these fission products [4].

## **1.2 Radioactive Waste**

Radioactive waste is an important part of hazardous products. The source of this waste is mainly nuclear power plants, industry, hospitals, research organizations and military nuclear tests and weapons [5]. Nuclear power plants are dangerous facilities put in practical use on the stipulation that they can “completely seal in radiation” while radioactive weapons scatter radioactive materials in the environment.

Types of nuclear waste: low and intermediate level waste, 77% long-lived, and 2% high level waste [6]. Depleted uranium (DU) is a by-product of the enrichment of natural uranium for nuclear reactor-grade or nuclear weapons-grade uranium.

Depleted uranium is chemically identical to natural uranium. DU is depleted with isotope of  $^{235}\text{U}$  and its radioactivity is 60% of the natural uranium and increases to 80% after few months and is usually considered as low level radioactive waste (LLW) [7-9]. On explosion it creates a poisonous radioactive cloud of fine dust that can spread by tens of kilometers [10]. Anybody who breathes these particles will have a permanent dose; it is not going to be decreased very much over time, and cause major problems [11,12].

Though DU is 40% less radioactive than natural uranium, its radiological and toxic effects might combine in subtle, unforeseen ways, making it more carcinogenic than thought depleted uranium is

"genotoxic". It chemically alters Deoxyribonucleic acid (DNA), switching on genes that would otherwise not be expressed.

The fear is that the resulting abnormally high activity in cells could be a precursor to tumor growth. Depleted uranium weapons alloy is 99.8%,  $^{238}\text{U}$ , emitting 60% of the alpha, beta, and gamma radiation of natural Uranium [13,14].

When the DU penetrates hits an object it breaks up and causes secondary explosions. Some of the uranium used with DU weapons vaporizes into extremely small particles, which are dispersed into the atmosphere where they remain until they fall to the ground with the rain.

As gas uranium oxides, the chemically toxic and radioactive depleted uranium can easily enter the body through the skin or the lungs and be carried around the world until it falls to earth with the wind and the rain [15].

### **1.3 Natural Radioactivity**

Aside from cosmic nuclides and the long-lived radioisotope K-40, the natural radioactivity in the ocean is primarily derived from the decay chain of three radionuclides, produced in the period of nucleosynthesis before our solar birth: uranium-238, uranium-232 and uranium-235 [16].

$^{40}\text{K}$  is a radioactive isotope of potassium which has a very long half - life of  $1.251 \times 10^9$  years. It makes up 0.012 % (120 ppm) of the total amount of potassium found in nature [17]. Potassium-40 behaves in the environment the same as other potassium isotopes, being assimilated into the tissues of all plants and animals through normal biological processes. It is the predominant radioactive component in human tissues and in most food [18].

Thorium (Th) is a naturally occurring, radioactive metal which has very long half -life of  $1.405 \times 10^{10}$  years [19].

Small values of thorium are existent in all rocks, soil, above earth and under earth water, plants, and animals. These small values of thorium contribute to the weak background radiation for such material. More than 99% of natural thorium exists in the form (isotope)  $^{232}\text{Th}$ . Besides this natural thorium isotope, there are more than 10 other various isotopes that can be artificially produced. In the environment,  $^{232}\text{Th}$  exists in various groups with other metals, such as silica. Most thorium compounds usually found in the environment do not dissolve easily in water and do not evaporate from soil or water into the air.

The thorium  $^{232}\text{Th}$  is not stable. It breaks down into two parts. This operation of breaking down is called decay. The decay  $^{232}\text{Th}$  produces a small part called "alpha" radiation and a large part called the decay product. The decay product of  $^{232}\text{Th}$  also is not stable, such as  $^{232}\text{Th}$ , it in turn breaks down to an unstable isotope and the operation continues until a stable product is created. During these decay operations, the parent  $^{232}\text{Th}$ , its decay products, and their next decay products produce a series of new material [20].

The value of radioactivity in soil varies to a large degree; hence it is important to observe the terrestrial background radiation mainly due to natural radionuclides in soil and the study of the radioactive components in soil is a fundamental link in understanding the behavior of radionuclides in the environmental system [21].

Uranium (U) is one of the most common radionuclides, all isotopes of uranium are radioactive, Uranium is weakly radioactive because all its isotopes are unstable. The most common isotopes of uranium are uranium-238 (which has long half-life  $4.5 \times 10^9$  years [22]).

Uranium has the second highest atomic weight of the primordially occurring elements, Uranium is existed almost in all soils, rocks and waters. Water passing through and over rock and soil structure solves

many compounds and minerals, including uranium, so varying amounts of it are existent in some water sources [23].

#### 1.4 Previous Studies

There are many studies have been performed to investigate and measure the concentrations of radioactive elements in food samples by using different techniques. These studies are abstracted as follows:

**Saeed M. *et al.* in 2011** : studied the radionuclide content and their level of radioactivity for six type of rice eaten by the Malaysian by using hyper pure germanium (HYGe) detector. The average concentration of Uranium, Thorium and Potassium were found to be in the range of  $(18.33-25.10) \pm 0.01 \text{ Bq.Kg}^{-1}$ ,  $(35.49-64.97) \pm 0.01 \text{ Bq.kg}^{-1}$  and  $(64.802-109.929) \pm 0.001 \text{ Bq.Kg}^{-1}$  respectively. Effective dose per annum was resided in the range of  $0.02 \mu\text{Sv.year}^{-1}$  to  $0.03 \mu\text{Sv.year}^{-1}$  [24].

**Al-Zahrani J. in 2012** : studied twenty five samples of infant's milk used in Saudi Arabia (Jeddah city) by using a NaI (TI) detector 3x3 inch .The main detected activity corresponding to  $^{40}\text{K}$  was  $234.18 \pm 1.9 \text{ Bq.Kg}^{-1}$ , while the average activities of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  were  $0.46 \text{ Bq.Kg}^{-1}$ , and  $0.35 \text{ Bq.Kg}^{-1}$ . The total average effective dose due to annual intake of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  from the ingestion of the powdered milk for infants were estimated to be  $410 \mu\text{Sv}$  for infant  $\leq 1\text{Y}$  and  $157 \mu\text{Sv}$  for infants (1-2Y) , which are lower than allowed value [25].

**Al-Hamidawi A. *et al.* in 2013** : studied the  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  with the specific activity for ten samples of legumes that are available in the Iraqi market using gamma spectrometry method with NaI(Tl) detector. It was found that the specific activity in legumes varied from  $1.450 \pm 0.096$  to  $12.307 \pm 0.387 \text{ Bq.Kg}^{-1}$  for  $^{238}\text{U}$ , from  $0.371 \pm 0.058$  to  $9.289 \pm 0.465 \text{ Bq.Kg}^{-1}$  for  $^{232}\text{Th}$ , and from  $64.096 \pm 1.037$  to  $603.397 \pm 8.757 \text{ Bq.Kg}^{-1}$  for K-40. The results were compared with

international recommended values and were found to be within the international level [26].

**Alrefae T. and Nageswaran T. in 2013 :** studied  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for 21 samples by using a high purity germanium (HPGe) p-type detector, in addition to the anthropogenic radionuclide  $^{137}\text{Cs}$ . Annual effective doses from rice consumption were estimated to be 33 and 60  $\mu\text{Sv}$  for the adult and child age groups respectively, rice consumption in Kuwait is radiologically safe for the presence of the investigated radionuclides [27].

**Islam A. et al. in 2014 :** determined the radioactivity concentrations of  $^{226}\text{Ra}$ ,  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in 10 samples vegetables of a recently found high background radiation area of south-eastern part of Bangladesh and to detect the radiological risks to human from intake of these vegetables, 10 plant samples were collected randomly from different locations of the study area. The radio-nuclides in papaya were measured by direct  $\gamma$ -ray spectrometry using HPGe detector. The average activity concentrations of  $^{226}\text{Ra}$ ,  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in papaya samples were  $80.95 \pm 13.61$ ,  $64.77 \pm 38.47$ ,  $83.53 \pm 20.50$  and  $1691.45 \pm 244.98 \text{ Bq.Kg}^{-1}$  respectively. The annual effective ingestion dose due to intake of papaya was  $1.1 \text{ mSv.Y}^{-1}$  [28].

**Laith A. et al. in 2015 :** studied of natural radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in rice consumed in Nineveh Province. NaI (Tl) detector was used to measure the radionuclides level. The radioactivity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  ranged from 51.15 to 109.26  $\text{Bq.Kg}^{-1}$ , 13.67 to 71.97  $\text{Bq.Kg}^{-1}$  and 231.87 to 691.71  $\text{Bq.Kg}^{-1}$ . In order to evaluate the radiological hazard of the natural radioactivity, radium equivalent activity, gamma absorbed dose rate, internal and external hazard indices, gamma index and finally alpha index have been calculated. Hence rice consumption in Nineveh province Iraq is radio

logically safe for the presence of the investigated radionuclides [29] .

**Hashim A. and Najam I. in 2015** : studied alpha radioactivity concentration in ten various brands of rice was collected from Iraqi market by using alpha sensitive CR- 39 . The radon concentration and radium concentration in various brands of rice vary from  $1.252 \times 10^3$  Bq/m<sup>3</sup> to  $23.110 \times 10^3$  Bq/m<sup>3</sup> with an average  $6.940 \times 10^3$  Bq/m<sup>3</sup> 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/m<sup>2</sup>.h to 374.051 mBq/m<sup>2</sup>.h with an average 105.212 mBq/m<sup>2</sup>.h [30].

**Abojassim A. et al. in 2016** : studied the average specific activities in 40 samples for <sup>238</sup>U, <sup>232</sup>Th and <sup>40</sup>K by using Gamma ray spectroscopy with scintillation detector NaI(Tl) were 5.21, 4.76, and 186.15 Bq kg<sup>-1</sup>, respectively, the average specific activities for <sup>232</sup>Th, <sup>40</sup>K in fruit samples were 2.53, 211.64 Bq Kg<sup>-1</sup>, while the total average annual effective dose in vegetables samples for adults, children (10 years old) and infants is estimated to be 0.117, 0.122, and 0.179 mSv, respectively, while the total average annual effective dose in fruit samples for adults, children (10 years old) and infants is estimated to be 0.141, 0.295, and 0.388 mSv, respectively [31] .

**Trdin M. and Benedik L. in 2017:** determined the activity concentrations of particular radionuclides in infant formulas available on the Slovenian market. <sup>238</sup>U, <sup>234</sup>U, <sup>230</sup>Th and <sup>210</sup>Po activity concentrations by using HPGE detector were determined in five samples and dose assessment was carried out with dose coefficients listed in the International Atomic Energy Agency (IAEA). The results obtained show that the main contributors to the estimated cumulative radiation dose (230 to 350 μSv y<sup>-1</sup>) is <sup>210</sup>Po [32].

**Abass K. et al. in 2017 :** measured radon and uranium concentration in a set of commercial children's milk consumed in Iraq using nuclear track detector CR-39 ,the results were obtained the highest value of radon concentration in Dialak2 sample equal to (2607.3170 Bq/m<sup>3</sup>) while the lowest value of radon concentration in Dialak1 sample equal to (782.1950 Bq/m<sup>3</sup>). The results were shown that the radon gas and uranium concentrations are in the limited values of IAEA that equal 2 ppm [33] .

**Abualhail R. et al. in 2017 :** measured the radioactivity levels of <sup>238</sup>U, <sup>232</sup>Th, <sup>40</sup>K and <sup>137</sup>Cs in 17 brands of flour consumed in Basra, Iraq by using gamma-ray NaI (TI) detector. For flour samples, the minimum specific activity values of <sup>238</sup>U, <sup>232</sup>Th, <sup>40</sup>K and <sup>137</sup>Cs were 0.238±0.002 , 0.117±0.001,3.529±0.001,and 0.040±0.007 Bq/Kg respectively, while the 111-F,102.348±0.001,and0.179±0.003 Bq/Kg respectively. All achieved results have been found to be under the international limit standards. Thus, selected flour and macaroni types are safe to be consumed in Basra governorate [34] .

**Salih N. in 2018 :** studied the concentrations of <sup>226</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K and their radiological hazards in 18 types of grain samples, collected from local markets in Penang, Malaysia by using high-purity germanium detector (HPGe). The results indicated that the concentration of <sup>226</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K in grain samples was ranged from 56.97 to 86.13 Bq.Kg<sup>-1</sup>, from 34.71 to 52.14 Bq.Kg<sup>-1</sup>, and from 517.05 to 997.59 Bq.Kg<sup>-1</sup>, respectively. The results of the average annual ingestion dose of natural radionuclides of <sup>226</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K were found to be 66.555, 35.199, and 15.328 μSv.y<sup>-1</sup>, respectively. These results are below the standard worldwide value (290 μSv.y<sup>-1</sup>) that was reported by UNSCEAR [35] .

**Tayseer I. and Doaa H. in 2018 :** determined radon-222 concentration,

and effective radium content for different types of household foods (coffee, powder milk, tea, powder coconut, rice, cornstarch, flour, and sugar) used in Egypt by using CR-39 polymer track detector, it is found a large variations in the values of radon concentrations, and effective radium content for all the samples. Annual effective dose was determined in this study, and its maximum value was 17.70  $\mu\text{Sv/y}$  which was found in sugar and the lowest value of its was 4.29  $\mu\text{Sv/y}$  which was found in coconut powder [36].

**Alrefae T. et al. in 2018 :** investigated the natural radioactivity in flour consumed in Kuwait. The activity concentrations of the three radionuclides were  $^{226}\text{Ra}$  detected in all samples, with a maximum value of  $8.08 \pm 0.42 \text{ Bq.Kg}^{-1}$  (a gram flour from India), a minimum value of  $0.42 \pm 0.02 \text{ Bq.Kg}^{-1}$  (a rice flour from Kuwait) and an all-sample average of ( $\pm \text{SD}$ )  $3.00 \pm 1.84 \text{ Bq.Kg}^{-1}$ .  $^{228}\text{Ra}$  was detected above the minimum detectable activity (MDA) in 14 samples, and was not detected in 3 samples. The maximum, above MDA, detected value was  $2.49 \pm 0.19 \text{ Bq.Kg}^{-1}$  (a white flour sample from Kuwait) [37].

**Garcêz, R. et al in 2018:** an investigation of the activity concentration (AC) of naturally occurring radionuclides in 26 samples of seasoning and nuts utilized for Brazilian population. The samples were measured using gamma spectroscopy technique with a high-purity germanium detector. The analysis shows that K-40 AC was measured in all samples, and its AC ranges from 21.0 Bq/kg to 1288 Bq/kg. The highest K-40 AC was measured for cheiro verde, a Brazilian seasoning made of chives (*Allium schoenoprasum*) and parsley (*Petroselinum crispum*)[38].

**Alsalihi A. and Abualhiall R. in 2019 :** investigated the radioactivity levels of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in 13 brands of dry legumes consumed in Basra, Iraq. By using gamma-ray NaI(Tl) detector .For

lentils samples, the minimum specific activity values of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were 0.178Bq/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  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  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 [39].

**Shanshal M. in 2019 :** used to estimate possible nuclear radioactive contamination in plant food consumed in Baghdad and its surrounding cities Considering the measurement results they obtained with the two different methods both Solid State Nuclear Track Detector (SSNTD), CR-39, and Geiger-Muller, one finds good similarity in the values of  $f(r)$  values i.e. measured dose/ tolerated dose. As for the values of the CR-39 measurements, they range from 0.32 to 0.5 and for the GS- GM results they range from 0.0 to 0.44. that however are still lower than 1 [40].

**Shakir A. and Muttaleb M. in 2020:** natural radionuclides in ten of the most available types of milk powder from local markets in Babylon government have been analyzed by means of a gamma – ray spectrometry NaI (TI) and estimated of the annual effective dose intake of the radionuclides .The concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  have been found to vary from  $(57.2645 \pm 1.853031)$  Bq.Kg<sup>-1</sup> to  $(0.299814 \pm 0.1340)$  Bq.Kg<sup>-1</sup> with , from  $(36.7284 \pm 1.422407)$  Bq.Kg<sup>-1</sup> to  $(0.37037 \pm 0.066679)$  Bq.Kg<sup>-1</sup> and from  $(481.521 \pm 5.65807)$  Bq. Kg<sup>-1</sup> to  $(268.0537 \pm 0.299814)$  Bq. Kg<sup>-1</sup> respectively [41] .

**Nusseif A. et al. in 2020 :** measured the concentration of radon gas in four milk samples collected from the local markets in Baghdad city. The results show that the highest average value was found in Rainbow

milk (Oman) and was equal to 44.045, while the lowest value of the average is found in the sample of Anchor milk (New Zealand) which was equal to 24.70133. Also, Results indicate that the concentrations of the all studied samples are less than the recommended value. While Annual effective dose (AED), surface exhalation rate and effective Radon content for all samples were below the global limits; therefore these types of milk can be considered safe to use as it relates to concentration of the radon [42].

**Al-Alawy, I. *et al* in 2020:** measured the concentrations of natural radionuclides in three plant species grown in the city of Al-Taji in the capital, Baghdad, were examined using NaI(Tl) gamma spectroscopy. The measurements were made on three parts of each plant sample which included roots, stalk, and leaves in addition to soil. The assessing of transport factors shows the K-40 transfer coefficients were lower than those values mentioned in other previous studies. The mean concentrations of specific activity for U-238, Th-232 and K-40 in the basil plant were  $4.455 \pm 2.944$ ,  $18.774 \pm 14.998$  and  $123.767 \pm 23.047$  Bq/kg respectively [43].

**Oyindamola P. *et al.* in 2021:** radiological assessment of fruits, vegetables, grains and tuber crops cultivated and consumed in Okemesi township, Ekiti State has been carried out by using a 76mm by 76mm lead-shielded Sodium Iodide detector (NaI(Tl)) located at the Centre for Energy, Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria. The mean activity concentration of the radionuclides in the food samples was  $155.76 \pm 14.22$  Bq.Kg<sup>-1</sup> for <sup>40</sup>K,  $8.00 \pm 0.24$  Bq.Kg<sup>-1</sup> for <sup>238</sup>U and  $7.39 \pm 0.21$  Bq.Kg<sup>-1</sup> for <sup>232</sup>Th [44].

**Avwiri G. *et al.* in 2021 :** analysis of the radionuclide levels in both food crops and the associated farm soils were carried out via gamma-ray spectrometry, to obtain the TFs of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K from

agricultural farm soils to food crops. Banana exhibited the highest uptake of  $^{40}\text{K}$  with mean TF value of 2.66 and the lowest TF of 0.23 as estimated for beans. It is evident that all the food crops absorbs  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  more than  $^{40}\text{K}$ . The estimated effective dose due to ingestion of all the food crops ranges from  $26.82 \mu\text{Sv.y}^{-1}$  the results obtained show that in terms of the lifetime fatality cancer risk to adult [45].

**Ebraheem, R. et al. in 2021 :** using NaI(Tl) gamma spectroscopy to evaluate activity concentrations of natural radionuclides, artificial radio-cesium, and soil-to plant transfer factor in common different plants species grown at Abu-Ghraib city in the capital Baghdad. Five species of plants have been selected, namely green pepper, cucumber, celery, basil, and mint. The measurements were made on four parts of each plant sample which were included soil, roots, stalk, and leave for knowledge and evaluation the transfer factors. The maximum mean specific activity concentration of U-238 and Th-232 was  $9.853 \pm 10.904 \text{ Bq/kg}$ ,  $6.005 \pm 2.729 \text{ Bq/kg}$  in celery, while the maximum mean specific activity concentration of K-40 was  $141.172 \pm 71.703 \text{ Bq/kg}$  in cucumber, respectively [46].

**Esam S. et al. in 2022 :** evaluate the radioactivity of samples of foodstuffs Consumables in the local markets thirteen items were selected where the concentrations of the specific activity of the chains of uranium ( $^{238}\text{U}$ ), thorium ( $^{232}\text{Th}$ ) and potassium ( $^{40}\text{K}$ ) were measured using a gamma ray spectra analysis system with a high purity germanium (HPGe) where it was found that the specific activity, which is measured by the unit (Bq/Kg) of potassium ( $^{40}\text{K}$ ) in the studied samples ranged from (BDL  $-397.977 \pm 25.894$ ) with a rate of  $(143.559 \pm 10.616)$ , and for uranium  $^{238}\text{U}$  (BLD  $-7.114 \pm 0.877$ ) with a rate of  $(1.904 \pm 0.214)$  and thorium ( $^{232}\text{Th}$ ) B.L.D below level detection [47].

### **1.5 Aim of the Work Study**

The aims of the present study could be given in the following points:

1-Estimating the natural radionuclides of  $^{226}\text{Rn}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for different samples of foods that are available in some Iraqi markets, which is frequently consumed by the population of Iraq.

2- Estimating some of radiological parameters such as radium equivalent ( $\text{Ra}_{\text{eq}}$ ), Absorbed dose rate , internal hazard indices, annual effective dose for ingestion and activity concentration index.

3-Study the relation between the radioactivity rates of radionuclide and the rate of the number of people diagnosed with cancer in some Iraqi governorates.

## **2. Introduction**

Ionizing radiation is a form of energy that acts by removing electrons from atoms and molecules of materials that include air, water, and living tissue. Ionizing radiation can travel unseen and pass through these materials. Non-ionizing radiation is a form of radiation with less energy than ionizing radiation. Unlike ionizing radiation, non-ionizing radiation does not remove electrons from atoms or molecules of materials that include air, water, and living tissue [48].

Ionizing radiation injures tissues variably, depending on factors such as radiation dose, rate of exposure, type of radiation, and part of the body exposed. Ionizing radiation is emitted by radioactive elements [49].

### **2.1 Radioactive Decay**

The spontaneous decay of an unstable nuclide into a more stable nuclide, as the decay of radioactive nuclei is subject to an exponential law developed by Rutherford and Soddy in 1902 and then modified by the scientist Bateman 1910.

The nucleus can emit several types of radiation and this depends on the intrinsic property of the nucleus, and the possibility of emitting radiation is a random interaction that does not depend on the conditions surrounding the nucleus, the pressure on it or its temperature...etc. Also, the possibility of nucleus decomposition does not depend on the age of the nucleus, as the nucleus may remain without decomposition for millions of years before it suddenly decomposes and emits certain types of radiation [50].

Suppose that  $N$  number of radioactive nuclei are present in a given sample at time  $t$  that have not yet been resolved. So, the degenerate

number  $dN$  over a period of time  $dt$  (that is, from  $t$  to  $t + dt$ ). It must fit  $N$  and  $dt$  according to the following equation [50, 51]

$$-dN \propto Ndt \quad (2.1)$$

A negative sign shows the number of radioactive nuclei is decreasing. So that:

$$-dN = \lambda Ndt \quad (2.2)$$

Whereas,  $\lambda$  is a constant quantity and is called the disintegration or decay constant, which represents the probability of the dissolution of any radioactive nuclei per unit time, or the fraction of nuclei present in a given sample that dissolves per unit time. Therefore, the decay constant can be written according to the following form:

$$\lambda = -\frac{(dN/dt)}{N} \quad (2.3)$$

We calculate the number of radioactive nuclei  $N(t)$  present in any time period  $t$ . This is known as the law of dissolution. By using the Equation:

$$\int_{N_0}^N dN/N = \int_{t=0}^t -\lambda dt \quad (2.4)$$

Integration between systems and systems. Time at  $t = 0$ ,  $N = N_0$ . In time, the number of nuclei is equal to ( $N = N(t)$ ). Thus:

$$\ln N = -\lambda t + c \quad (2.5)$$

Since  $c$  is the constant of integration and its value is determined by the initial conditions, so:

$$\ln N_0 = 0 + c = c \quad (2.6)$$

By substituting the value of  $c$  into the equation (2.5), we get what is known as the power law of radioactivity dissolution or only the law of dissolution

$$N(t) = N_0 e^{-\lambda t} \quad (2.7)$$

Thus, this law can be written in terms of the radioactive activity (A), which is defined as the disintegration rate of radioactivity:

$$\text{Activity}(A) = -\frac{dN}{dt} = \lambda N \quad (2.8)$$

The radioactive activity (A) can also be obtained from Equation (2.7) by multiplying its two sides by the decay constant ( $\lambda$ ), if we know the initial activity  $A_0$  or the initial number of radioactive nuclei  $N_0$

$$A(t) = A_0 e^{-\lambda t} \quad \text{or} \quad N(t)\lambda = N_0 \lambda e^{-\lambda t} \quad (2.9)$$

This means that the radioactive activity, which is also called radioactivity in general, is equal, at time  $t = 0$ , to  $A_0 = \lambda N_0$ . At any other time  $A(t) = \lambda N(t)$ .

## 2.2 Radioactivity chains

radioactivity series, nuclei that have a number greater than (82) simply by activity, due to the increase in the number of protons in the large output Electrostatic repulsion This leads to the repulsion to the disintegration of some nuclei with the release of alpha particles in turn starting in a ratio neutrons to protons in the nascent nuclei lead to their disintegration with the release of beta particles, and so the chain continues until it reaches the end in the end to a stable nucleus, often the lead nucleus. Nature has four groups known as the natural radiation chains, which are the uranium , actinium chains , thorium series and the neptunium series [52] .

### 2.2.1 Uranium-238 series

The percentage of uranium  $^{238}\text{U}$  is 99.25% of natural uranium. It decomposes by emission alpha particle to turn into thorium  $^{234}\text{Th}$ , which is made radioactive. It also decays by emission of a negative beta particle and turns into protactinium  $^{234}\text{Pa}$ . The chain continues to decompose into stable lead  $^{206}\text{Pb}$  and its general mass formula  $(4n + 2)$  where  $n$  is an

integer.

The presence ( $^{226}\text{Ra}$ ) is the evidence for the presence of  $^{238}\text{U}$  in the example shown in the figure resulting from  $\gamma$ -decay, or the measurement of  $\alpha$ -rays resulting from the decay of its offspring radon-222. Fig. (2.1) shows the  $^{238}\text{U}$  series [53].

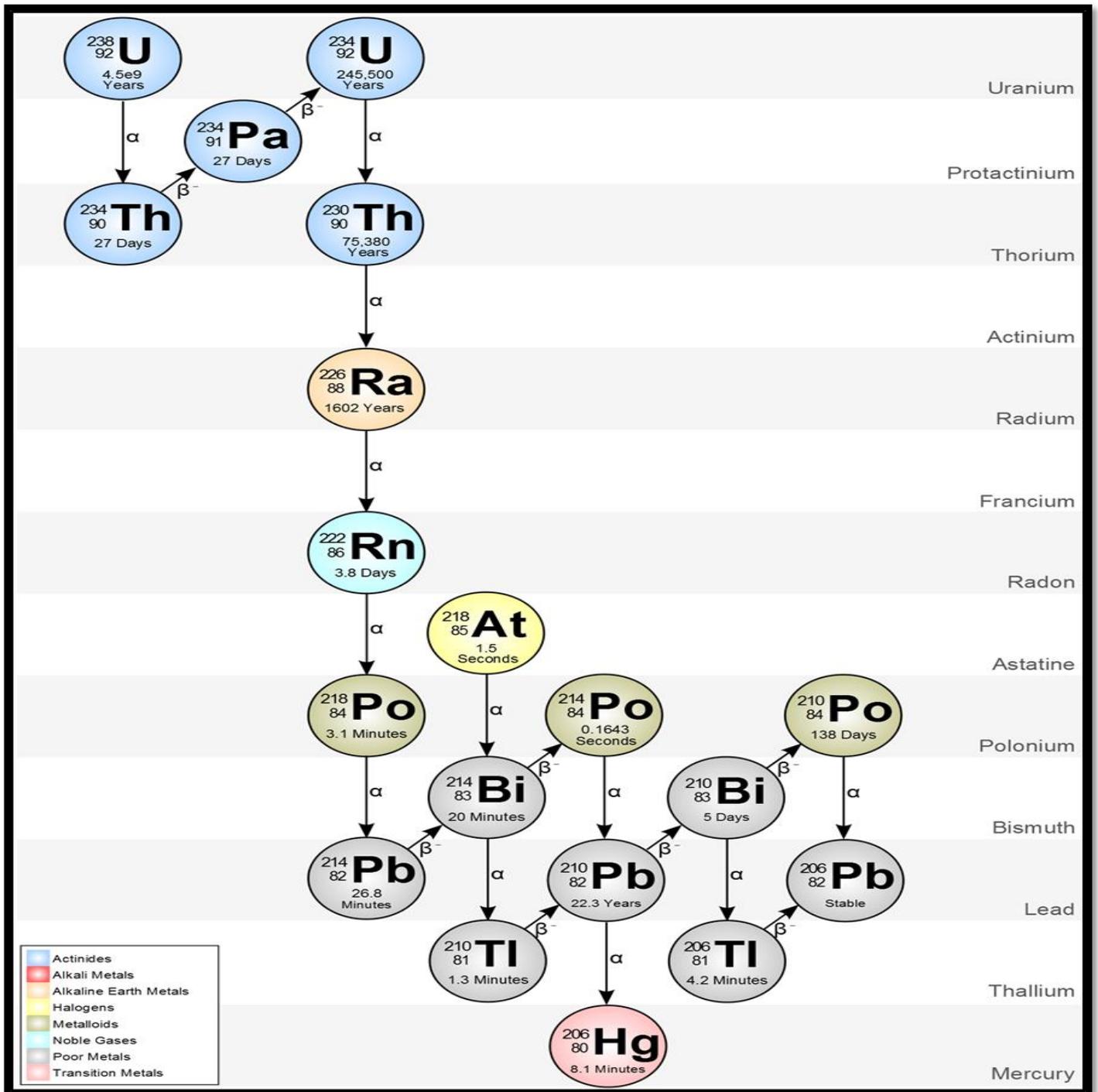


Figure (2.1):Uranium-238 Series [54].

2.2.2 Thorium Series

Thorium is found in nature of abundance (100%) and this series begins with the isotope ( $^{232}\text{Th}$ ) and suffers a number of decays to end with the stable isotope lead-208 ( $^{208}\text{Pb}$ ), as in Fig.( 2.2) [53] .

Each member of this chain has a mass number of A that is a multiple of 4, so  $A = 4n$ . The longest-lived member of the chain is thorium-232, The lifetime  $14.1 \times 10^9$  of this chain is about six times longer than that of the earth [51].

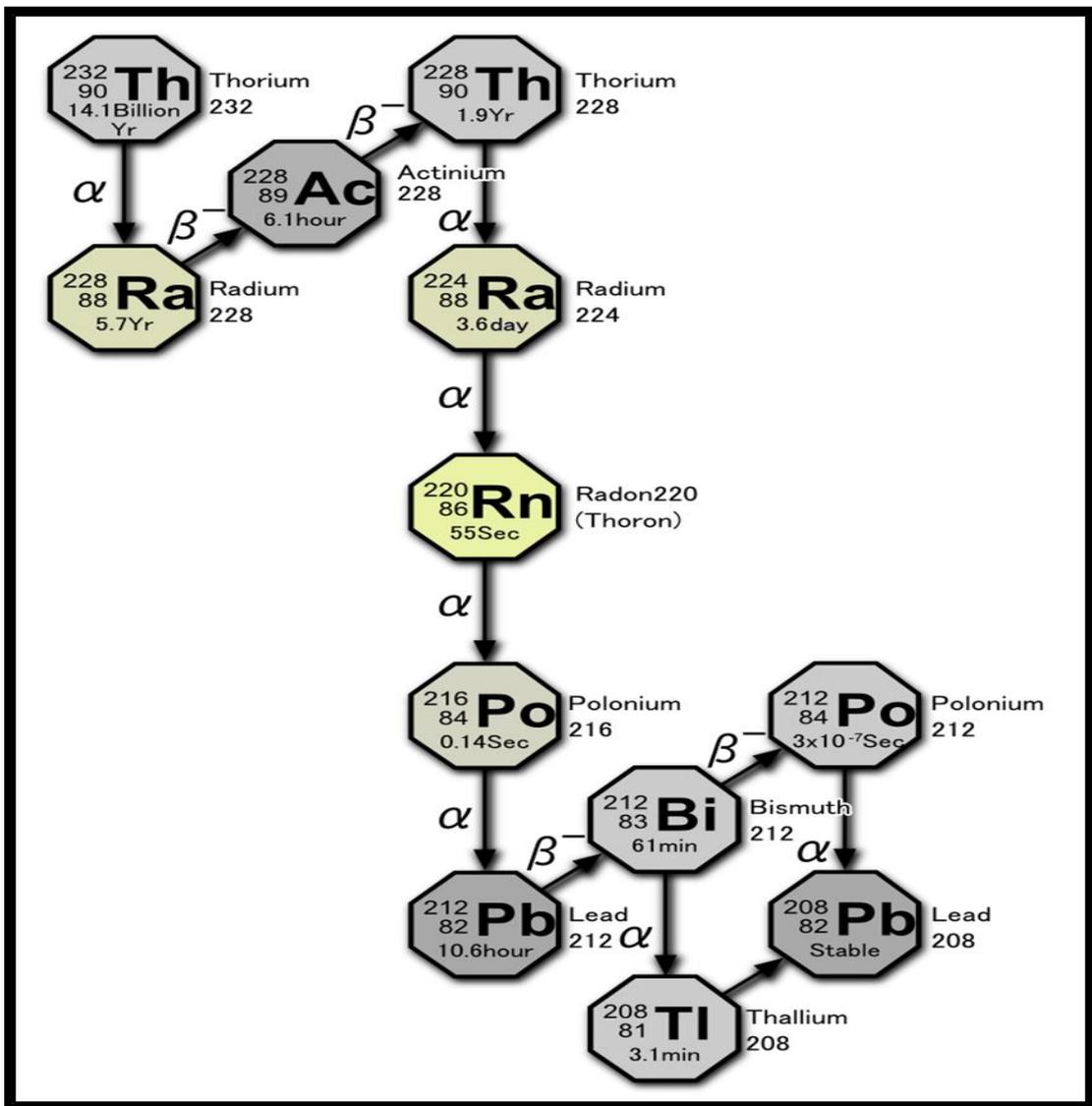
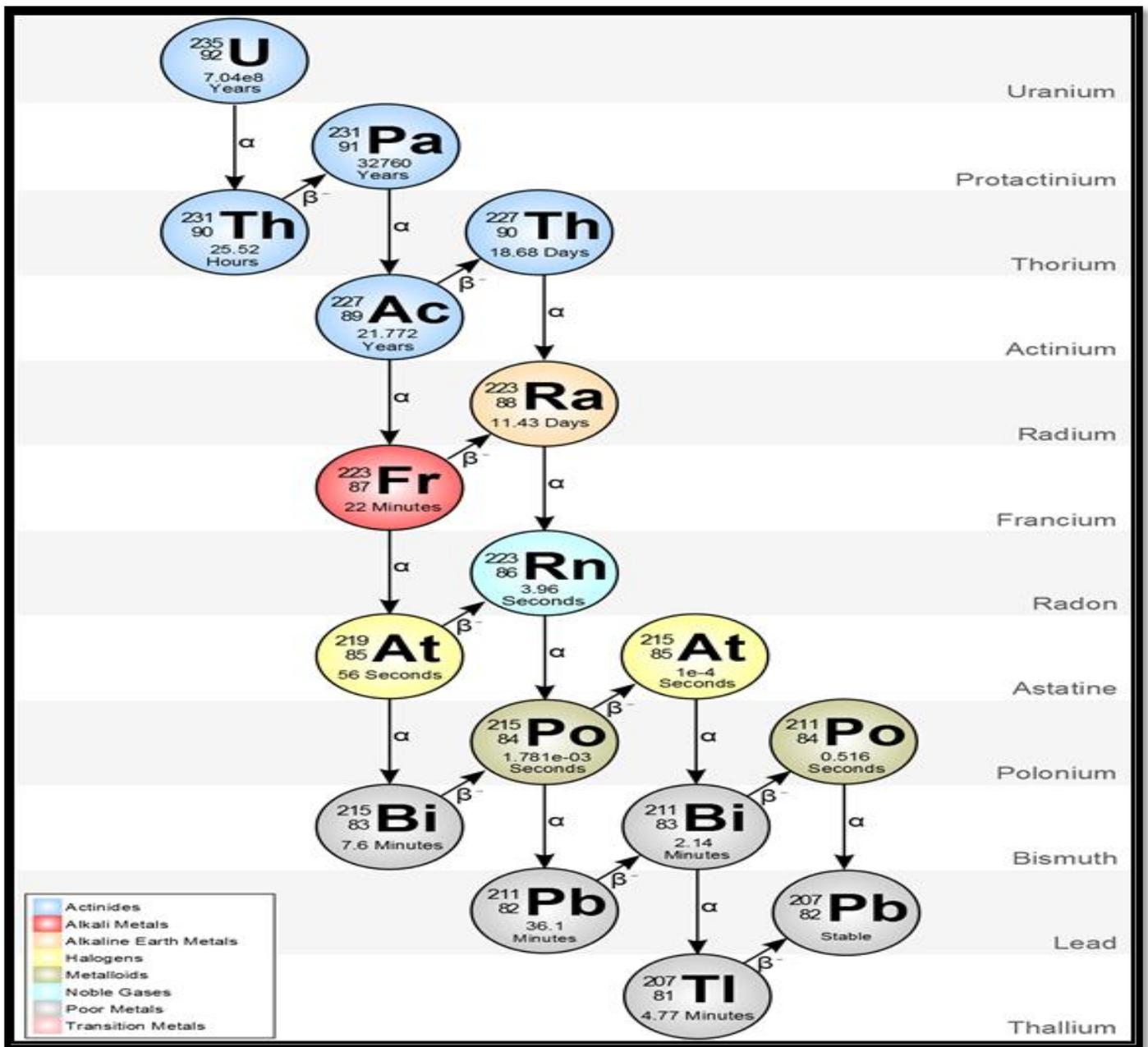


Figure (2.2) : Thorium-232 Series [54] .

2.2.3 Actinium Series

The uranium-235 series is called the actinium series or the (4n+3) series, and the percentage of uranium-235 is (0.72%) of the uranium percentage, where this series begins with the element uranium-235 and ends with the stable element lead-207, as shown in Fig. (2.3 ) [55].

This chain is the only one in nature that is split by slow neutrons. The most important element of it is  $^{235}\text{U}$  (half-life of  $7.04 \times 10^8$  years).

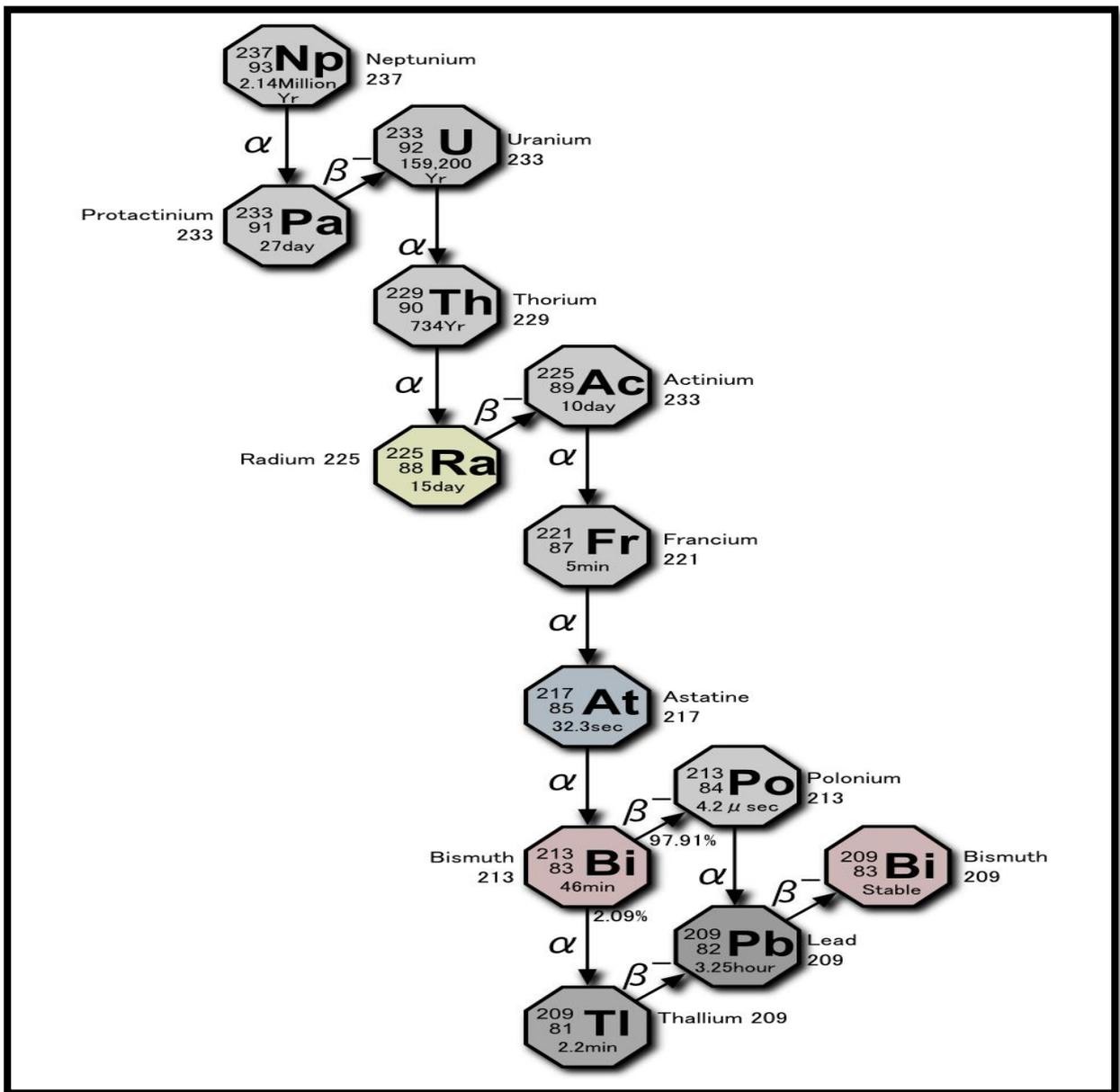


Figure(2.3): Actinium Series U-235 Series [54].

**2.2.4 Neptunium Series**

This series does not exist in nature at present, as the half-life of its longest elements is  $(2.2 \cdot 10^6)$  year, which is much smaller than the age of the earth, which is estimated at about  $(4-5 \cdot 10^6)$  year, that means it has turned into stable nuclei, which are the nuclei of bismuth-209 [52].

This chain begins with the mother nucleus  $^{237}\text{Np}$  (the longest-lived nucleus), and it is the only one that ends with the stable isotope of bismuth  $^{209}\text{Bi}$  instead of lead [51]. Fig.(2.4) shows the neptunium chain.



**Figure(2.4): Neptunium Series [54 ].**

## 2.3 Radioactive Equilibrium

In physics of nuclear decays, a radioactive equilibrium exists when a radioactive nuclide is decaying at the same rate at which it is being produced. The disintegrating nucleus is usually referred to as the parent nucleus and the nucleus remaining after the event as the daughter nucleus, the daughter nucleus can either be stable or radioactive. If it is radioactive, then it decays into a daughter nucleus and so on. Each radioactive parent nucleus can initiate a series of decays, with each decay-product having its own characteristic decay constant.

Concentration of daughter nuclei in the radioactive equilibrium depends primarily on proportions of half-lives (or decay constants) of parent and daughter nuclei. Since the production rate and decay rate are equal, the number of atoms remains constant over time. In any case, a radioactive equilibrium is not established immediately, but it only takes place after a transition period. This period is of the order of few half-lives of the longest-lived nucleus in the decay chain. In case of radioactive decay chains, a radioactive equilibrium may be established between each member of the decay chain [ 56,57] .

$$N_p\lambda_p=N_d\lambda_d \quad (2.11)$$

Where  $N_p$ : the number of atoms for the parent nucleus.

$N_d$ : the number of atoms for the daughter nucleus.

$\lambda_p$ : the radioactive decay constant of the parent nucleus.

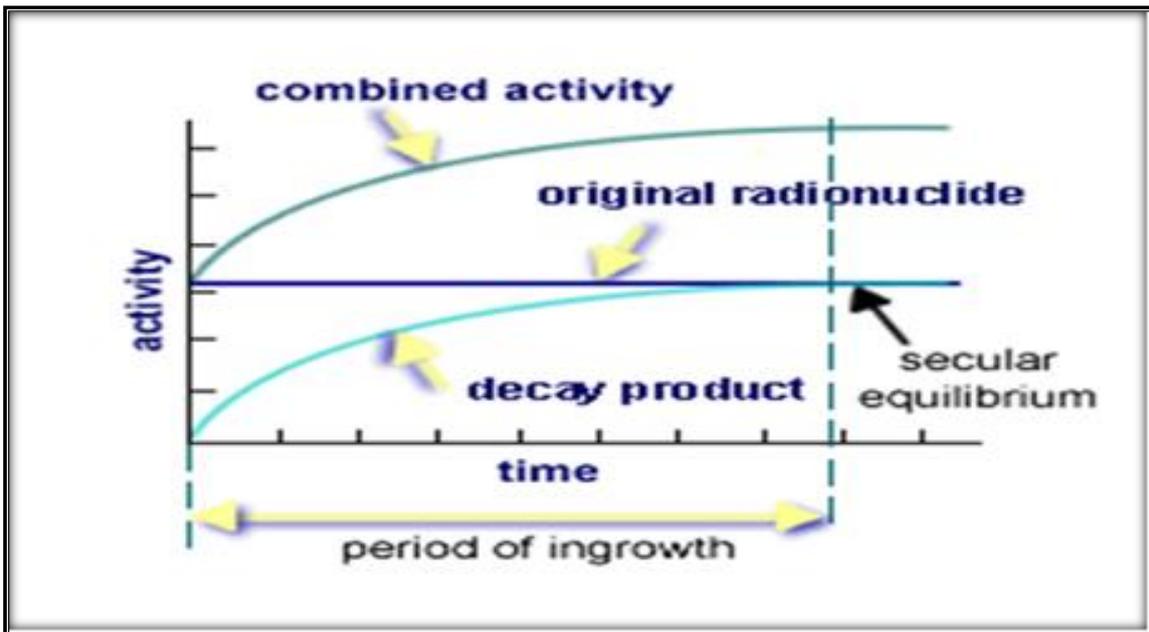
$\lambda_d$ : the radioactive decay constant of the daughter nucleus.

As was written, proportionality of half-lives is a key parameter, which determines type of radioactive equilibrium:

### 2.3.1 Secular Equilibrium

Secular radioactive equilibrium exists when the parent nucleus has an extremely long half-life as shown in Fig.(2.5). Secular equilibrium is

typical for natural radioactive series, such as the thorium series or the uranium series. For the uranium series with uranium-238 (with a half-life of 4.47 billion years), where all of the elements in the chain are in secular equilibrium, each of the descendants has built up to an equilibrium amount and all decay at the rate set by the original parent. The only exception is the final stable element (lead-206) on the end of the chain. Its number of atoms is constantly increasing. In any case, a radioactive equilibrium is not established immediately, but it only takes place after a transition period. This period is of the order of few half-lives of the longest-lived nucleus in the decay chain ( $^{234}\text{U}$  for the uranium series;  $^{231}\text{Pa}$  for the actinium series). In case of radioactive decay chains, a radioactive equilibrium may be established between each member of the decay chain [58 ].



**Figure(2.5): Secular Equilibrium [59].**

As can be seen, the secular equilibrium is particularly important in nature. Over the 4.5 billion years of the Earth's history, especially uranium- 238, uranium -235 and thorium -232 and members of their decay chains have reached radioactive equilibria between the parent

nucleus and the various descendants. The half-lives of all their descendants are all extremely variable, and it is difficult to represent a range of timescales going from individual seconds to millions of years. Since daughter radioisotopes have different half-lives then secular equilibrium is reached after some time. In the long decay chain for a naturally radioactive element, such as uranium-238, where all of the elements in the chain are in secular equilibrium, each of the descendants has built up to an equilibrium amount and all decay at the rate set by the original parent. when equilibrium is achieved, each successive daughter isotope is present in direct proportion to its half-life (or to its decay constant).

### 2.3.2 Transient Equilibrium

Transient Equilibrium is a condition reached when  $t_{\text{phys}}$  of the parent is approximately 10 times greater than the  $t_{\text{phys}}$  of the daughter as shown in Fig. (2.6). A classic example is the Mo-99/Tc-99m Generator, where the ratio of the half-lives is 67 hr/6 hr = 11:1. During the 60 hr period representing 10 half-lives of Tc-99m, almost 50% of the Mo-99 has disappeared, as noted in diagram. This represents a very significant amount, unlike the negligible amount in secular equilibrium.

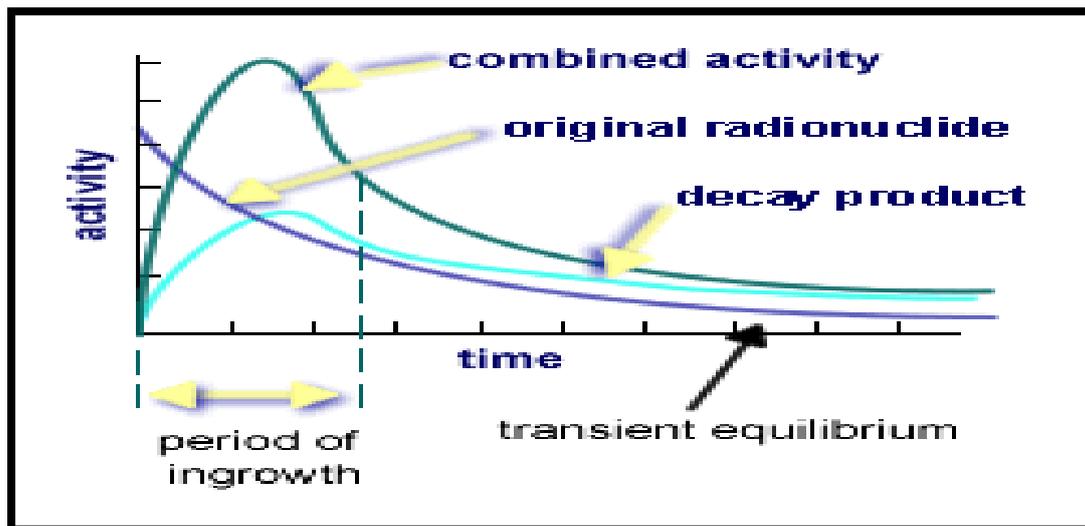
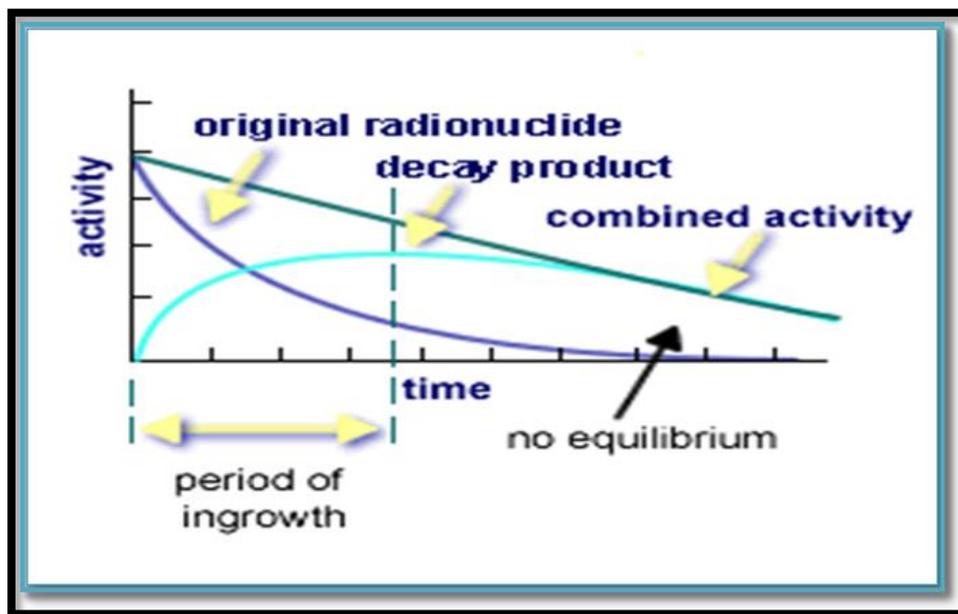


Figure (2.6): Transient Equilibrium [59].

**2.3.3 Non Equilibrium**

If the half-life of the nucleus is smaller than the half-life of the daughter nucleus as shown in Fig.(2.7), in this case the mother dissolves, leaving the girl alone, in other words, the work of the daughter nucleus will increase until the number of atoms of the parent nucleus runs out and then representation after that and the effectiveness of the nucleus decreases gradually decreasing with time In this case, equilibrium never occurs [60].



**Figure (2.7): Non Equilibrium [59].**

**2.4 Pathophysiology of Radiation Exposure**

ionizing radiation can damage DNA, Ribonucleic Acid (RNA), and proteins directly, but more often the damage to these molecules is indirect, caused by highly reactive free radicals generated by radiation's interaction with intracellular water molecules. Large doses of radiation can cause cell death, and lower doses may interfere with endogenous molecular repair systems, homeostasis, and cellular proliferation. Damage to these and other cellular components can result in progressive tissue hypoplasia, atrophy, and eventually fibrosis. However, it is now

clear that cell killing alone cannot explain many tissue reactions, because those reactions also depend on complex events including inflammatory, chronic oxidative, and immune reactions, as well as damage to the vasculature and the extracellular matrix. In general, early reactions, such as in the skin and gastrointestinal tract, involve killing of the stem/early progenitor cells that supply the mature functional cells in the tissue, as well as inflammatory reactions [61].

The gastrointestinal syndrome typically develops within five days of the initial exposure. At doses < 1.5 Gy, only the prodromal phase of nausea, vomiting, and gastric atony are observed [62]. More severe symptoms develop at doses between 5 and 12 Gy [63], loss of intestinal crypt cells and breakdown of the mucosal barrier. These changes result in crampy abdominal pain, diarrhea, nausea and vomiting, gastrointestinal bleeding with resultant anemia, and abnormalities of fluid and electrolyte balance. This early phase is often followed by a latent phase lasting 5–7 days, during which symptoms abate. Vomiting and severe diarrhea accompanied by high fever make up the manifest illness.

Systemic effects at this time may include malnutrition from malabsorption. Impaired barrier function of the gastrointestinal tract results in the passage of bacteria and their toxins through the intestinal wall into the bloodstream, predisposing to infection and sepsis, which may further be compromised by immunosuppression and cytopenia secondary to development of the hematopoietic syndrome. Other severe complications include ulceration and necrosis of the bowel wall, leading to stenosis, ileus, and perforation [62].

On the other hand, late reactions in the (lung, kidneys, and brain) involve complex and dynamic interactions between multiple cell types in the tissues and organs and include infiltrating immune cells, production of cytokines and growth factors, often in persistent, cyclic

cascades, and chronic oxidative stress [64].

## 2.5 Mathematical Formula

The specific activity of  $^{238}\text{U}$  and  $^{232}\text{Th}$  is measured by using property of secular equilibrium with their decay products such as transition lines of  $^{214}\text{Bi}$  (1764 KeV) and  $^{208}\text{Tl}$  (2614 KeV) respectively. While  $^{40}\text{K}$  is measured directly from the photo peak at 1460 KeV [65]. The measuring time for each sample under study is 18000 second.

### 2.5.1 Activity Concentrations

The activity concentrations for the natural radionuclides in the measured samples are calculated by using the following relation [66]:

$$A \text{ (Bq/Kg )} = N / (\varepsilon \cdot t \cdot I_{\gamma} \cdot M) \pm \sqrt{N} / (\varepsilon \cdot t \cdot I_{\gamma} \cdot M) \quad (2.12)$$

A: activity in( Bq/Kg ) N: net number of count of the corresponding full-energy peak, t : counting time in a second I<sub>γ</sub>: absolute transition gamma emission probability, M: sample weight (Kg), ε : efficiency of the detector in particular gamma energy and the activity.

### 2.5.2 Radiological Hazard Parameters

The theoretical equations that used in the calculation of activity concentration and risk factors of radioactivity are :

#### A. Absorbed Dose Rate (AD)

In order to assess radiological risk, external exposure to radiation arising from naturally occurring radionuclides can be determined in terms of the absorbed dose rate in air at 1 m above the ground surface. The conversion factors used to compute absorbed dose rate in air per unit activity concentration in Bq/l corresponds to 0.462 nG/h for  $^{226}\text{Ra}$ , 0.621 nG/h for  $^{232}\text{Th}$  and 0.0417 nG/h for  $^{40}\text{K}$  [67].

$$\text{AD (nGy/h)} = 0.462A_{\text{U}} + 0.621A_{\text{Th}} + 0.0417A_{\text{K}} \quad (2.13)$$

Where AD : is the dose rate,  $A_{\text{U}}$ ,  $A_{\text{Th}}$  and  $A_{\text{K}}$  are the activity concentration of uranium, thorium and potassium.

**B. Annual Effective Dose (AED)**

The annual effective dose is coming from consumption of food samples , and its determined by the formula (2.14), this quantity was considered to be among the most important due to the proportional relationship between its value and induced health effect from the intake of radionuclides

In order to measure the annual effective dose equivalent, conversion coefficients associated with the absorbed dose coefficients in the air are used. The amount of 0.7 Sv /Gy is used to convert modified coefficients of absorbed dose in air to effective dose received annually by adults and 0.8 is used as external occupation factor [68]:

$$AED_{in} = AD * 8760 \text{ (h/y)} * 0.8 * 0.7 \text{ (Sv /Gy)} * 10^{-6} \quad (2.14)$$

**C. Radium Equivalent Activity ( $Ra_{eq}$ )**

Is the most important to assess the radiation hazards and can be expressed using the relation [69]:

$$Ra_{eq} \text{ (Bq/Kg)} = A_U + 1.43A_{Th} + 0.077 A_K \quad (2.15)$$

Where  $A_U$ ,  $A_{Th}$ ,  $A_K$  are the specific activity levels (Bq/Kg) of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  respectively.

**D. Internal Radiation Hazard ( $H_{in}$ )**

The value of the internal risk arising from a short period of food can be calculated as follows [70]:

$$H_{in} = A_U/185 + A_{Th}/259 + A_K/4810 \quad (2.16)$$

If the value of the internal risk is less than one, it is within the permissible limits globally, and it is safe and does not constitute any danger.

**E. Activity Concentration Index ( $I_y$ )**

The radioactivity level index  $I_y$  used to measure radiation inside the human body and the risk level of radionuclides in human body when

exposed to an amount of indoor or outdoor annual effective doses of  $\gamma$ -radiations from radioactive nuclides .The estimated values of  $I_{\gamma}$  should be less than or equal to one . Values of  $I_{\gamma}$  were calculated from following formula [71]:

$$I_{\gamma} (\text{Bq/Kg}) = A_{\text{U}} /150 + A_{\text{Th}} /100 + A_{\text{K}} /1500 \quad (2.17)$$

### **3.1 Introduction**

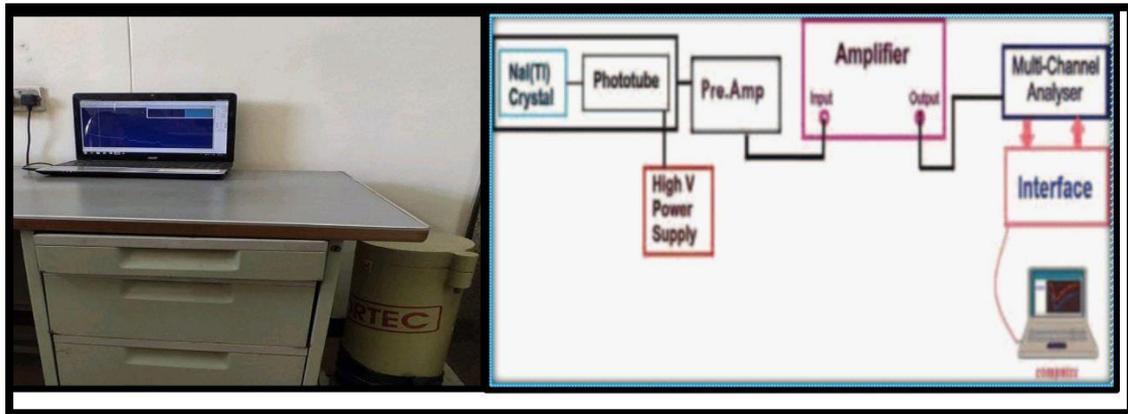
This chapter includes a brief review of the devices and materials used as well as the process that took place in this search for information to achieve the goal, the study in terms of the style of sampling and measurement of concentrations of the natural radionuclides of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for different samples of foods that are available in some Iraqi markets.

### **3.2 Detection System**

The radiological detection system represented by ORTEC foodGuard-1 NaI(Tl) is the company that designed the reagent shown in the Fig.(3.1) that examines all types of solid or liquid food and detects the extent of its contamination with radioactive materials.

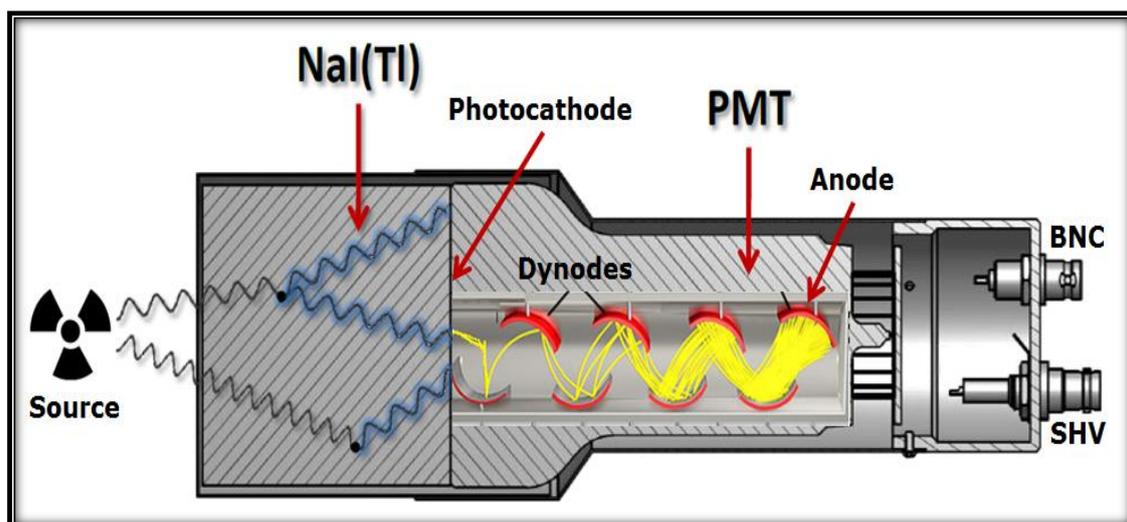
FoodGuard-1 is primarily designed for a 'frontline' response.

- 1- The counting is highly efficient and the sampling method is easy.
- 2- It displays the spectra and intuitive programming and a high degree of accuracy and stores the results.
- 3- The results can be obtained by calculations such as the percentage of maximum allowable concentration.
- 4- It can be moved from one place to another
- 5- The device is easily calibrated and contains containers for examining samples [72].



**Figure (3.1) : Schematic View of the Experimental System The NaI(Tl) Detector [73].**

The structure of the NaI(Tl) detector is illustrated in Fig.(3.2). It consists of a single crystal of thallium activated sodium iodide optically coupled to the photocathode of a photomultiplier tube.



**Figure (3.2): Schematic Picture of the Detector with NaI(Tl) Crystal, PMT and Connectors[74].**

When a gamma ray enters the detector, it will interact by causing ionization of the sodium iodide. This creates excited states in the crystal that decay by emitting visible light photons. This emission is called a scintillation. The thallium doping of the crystal is critical for shifting the wavelength of the light photons into the sensitive range of the photocathode. After the onset of the flash of light, the intensity of the

scintillation decays approximately exponentially in time, with a decay time constant of 250 ns. Surrounding the scintillation crystal is a thin aluminum enclosure, with a glass window at the interface with the photocathode. At the photocathode, the scintillation photons release electrons via the photoelectric effect. The number of photoelectrons produced is proportional to the number of scintillation photons, which, in turn, is proportional to the energy deposited in the crystal by the gamma ray.

The remainder of the photomultiplier tube consists of a series of dynodes enclosed in the evacuated glass tube. As each electron strikes the first dynode the electron has acquired sufficient kinetic energy to knock out 2 to 5 secondary electrons. Thus, the dynode multiplies the number of electrons in the pulse of charge. The secondary electrons from each dynode are attracted to the next dynode by the more positive voltage on the next dynode. This multiplication process is repeated at each dynode, until the output of the last dynode is collected at the anode.

The preamplifier collects the charge from the anode on a capacitor, turning the charge into a voltage pulse. Subsequently, it transmits the voltage pulse over the long distance to the supporting amplifier. At the output of the preamplifier and at the output of the linear amplifier, the pulse height is proportional to the energy deposited in the scintillator by the detected gamma ray. The Multichannel Analyzer (MCA) measures the pulse heights delivered by the amplifier, and sorts them into a histogram to record the energy spectrum produced by the NaI (TI) detector [75].

### **3.3 NaI(Tl) $\gamma$ - Ray Spectroscopy**

The absorption of the energy of the incident rays by the detector material causes electronic irritation in it and when the ray is removed a photon is produced within the visible energy region. This process is called luminescence. It is of two types: fluorescence, which occurs over a period of time of  $10^{-8}$  sec and results from the removal of irritation from Allowed transfer levels.

Phosphorylation: It occurs during a period of time  $10^{-6}$  sec of an amount or more that the cause of the delay in this type. Returns to the levels of irritation are almost stable levels to forbidden levels, so the process of removing irritation requires moving to a permissible level first and then returning to the ground level. The detector consists of a scintillation material and a photomultiplier [76 ].

#### **A. Scintillation Material**

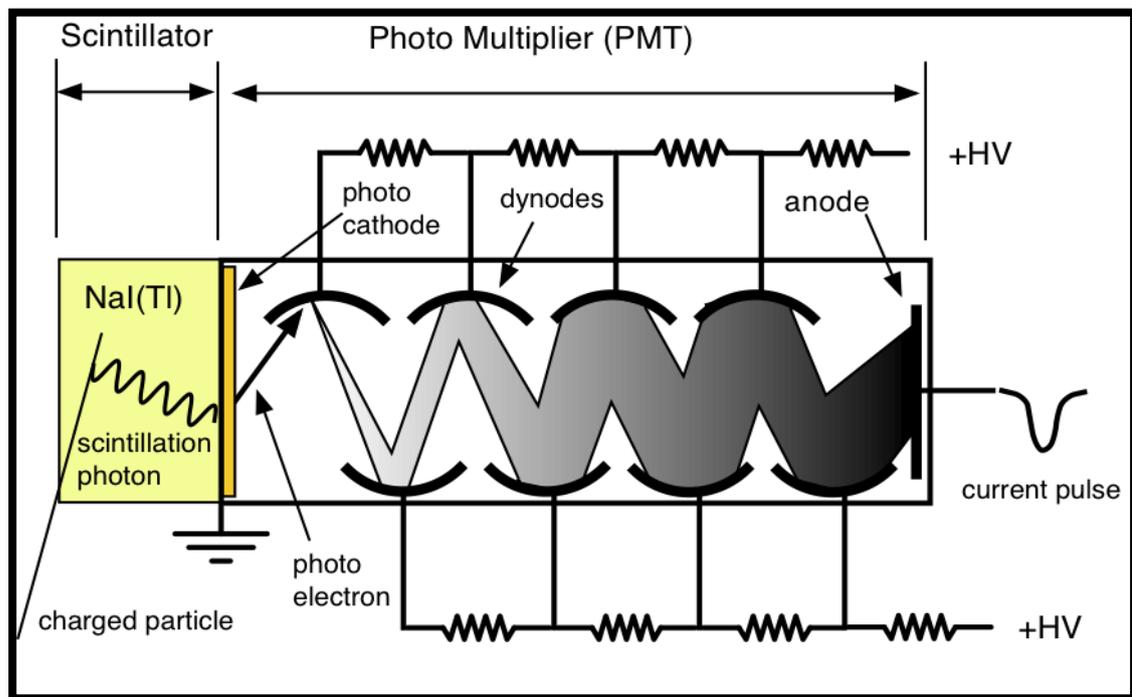
The counter head contains a sensitive crystal that is covered with a thin metal cover to be protected from the light falling on it so as not to cause damage to the crystal which consisting of sodium iodide affects PV.

The liberated electrons fall from the photocathode to the electrodes of the amplifying valve and multiply because of that large number of electric current. The sensitive crystal material is a special plastic material with its characteristics that it is transparent like inorganic salts, and it is possible to introduce certain liquids in use [77]. Fig.( 3.3) Schematic of scintillator and photo multiplier (PMT).

#### **B. Photo Multiplier**

The photomultiplier is an instrument that can detect photons. An incoming photon (a scintillation photon) hits the photo-cathode and via photo effect releases an electron. The probability for this process is

about 20% , so you need on the average 5 photons to produce a single photo-electron. The released electron is then accelerated toward a metal plate called a dynode where upon impact it releases more electrons, typically 2. These in turn are accelerated to the next dynode where each electron knocks out 2 more electrons. In this manner one obtains an exponentially growing number of electrons. At the end all the released electrons are collected at the anode where they produce a short, measurable electric current pulse [78].



**Figure (3.3): Schematic of Scintillator and Photo Multiplier (PMT)[78].**

### 3.4 Global Positioning System (GPS)

The Global Positioning System (GPS) as shown in Fig.(3.4). The GARMIN eTrex Vista is very easy to use thanks to its click stick and user friendly, graphical interface. It supports multiple languages and it has an integrated world map (overview) plus a detailed map of Europe, Africa

and the near east. Beside the GPS receiver, the eTrex Vista has an electronic compass and a barometrical altimeter. In addition, it has 24 MB of built-in memory to store even more detailed information, such as local roads, restaurants and points of interest. The extremely sensitive antenna provides navigation information outdoors, in a car, in a train or even in an airplane. When you turn on the eTrex Vista C, the GPS receiver begins to search for satellites in order to determine (fix) its location.

This process is called "initialization" and can take from 5 to 15 minutes at the first time when the unit is used. Thereafter, if the user hasn't moved more than 600 miles from the original location, it takes only seconds to minutes. In order to receive satellite signals, that must be outdoors and have a clear view of the sky. Satellite signals cannot pass through solid materials (except glass) or dense overhead tree cover. To shorten the time required for initialization, "New Location" will be selected from the options menu, then using the map page to determine the general location so the eTrex Vista C can search for those satellites above the user [79].

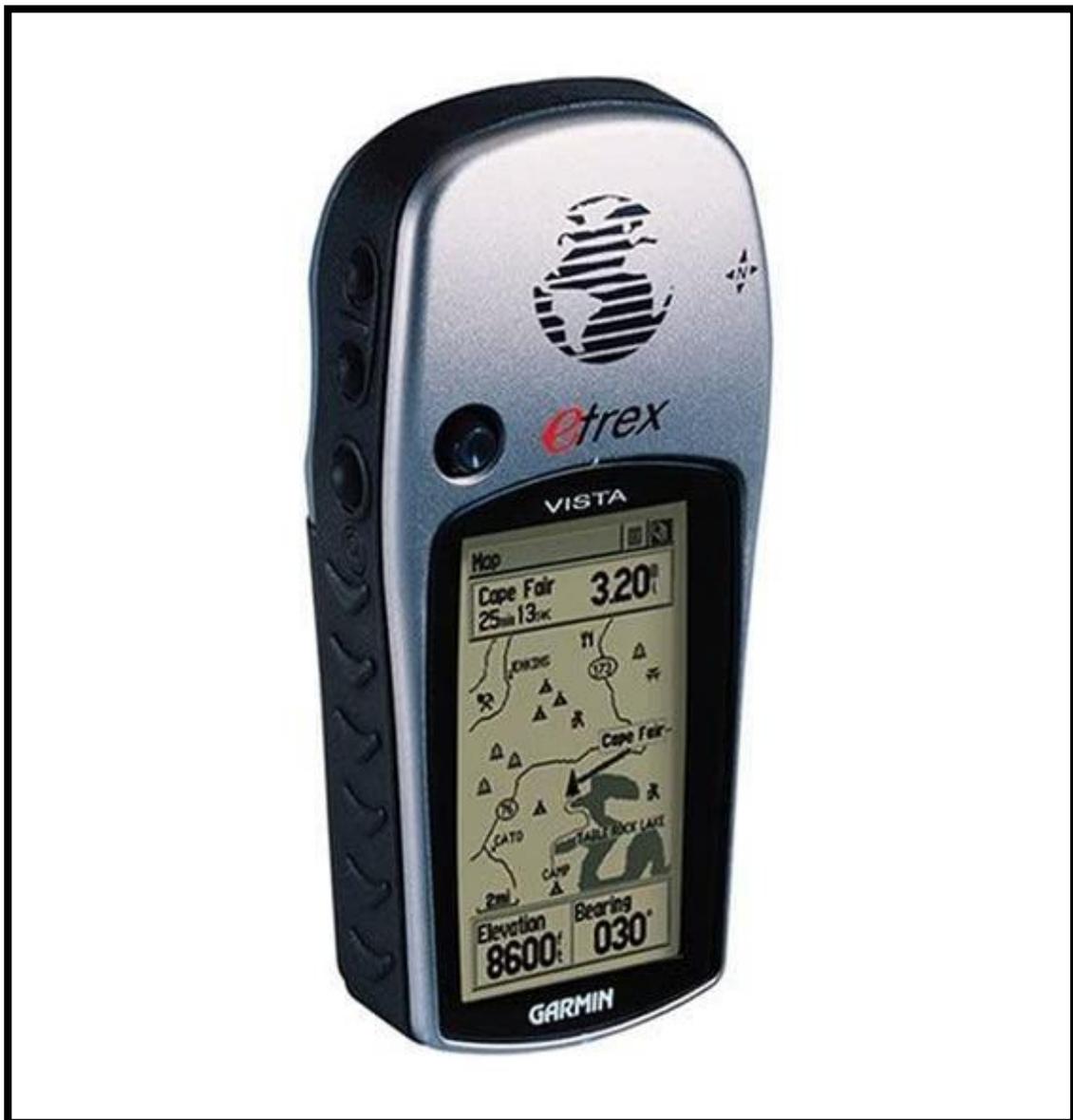


Figure (3.4): Global Positioning Device [79].

### 3.5 Genstat (General Statistics)

The (Genstat) program consists of 3 parts: the server, the user, and the part responsible for statistical fees. The (Genstat) program is used on the computer, and the interface that appears to you is the user interface that gives the user a list that helps to enter information, which can be included in the form of Excel tables. Or copy data from other files, write commands in the language (Genstat) or choose commands from the list in

the software, then all of this is transmitted to the server that shows the final results to the server, and the final results and fees can be saved on the program, and the entered data and all the modifications that have been made can be saved on it [80].

The steps to use GenStat Discovery Edition are as follows 1- Click on the GenStat icon on the desktop or from the toolbar or choose to select GenStat executable, from the list of programs. After opening GenStat , a Windows interface appears containing a menu bar, title bar, toolbar, status bar, and others.

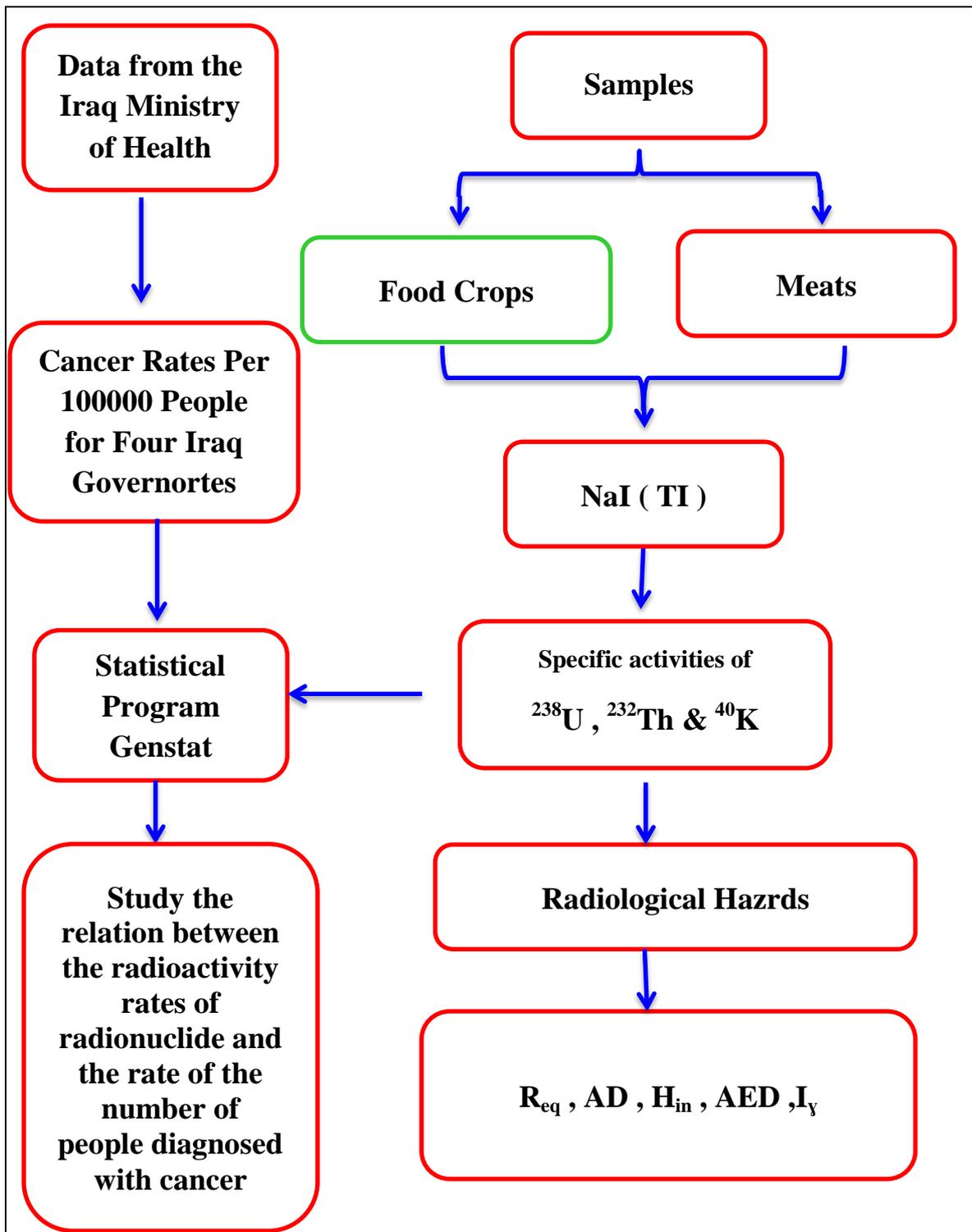
The output window contains the output of the operations it performs. The entry log is kept of everything that was accomplished in the analysis. Contains standard lists of running Windows applications, data, spread, graphics, and statistics for GenStat [81].

## **Chapter Four Results, Discussion and Calculations**

### **4.1 Food samples**

Seventy six samples of vegetables , leafy vegetables , fruits and meat are collected from Markets of four area (Al-Tuwaitha village which is located at southeast of Baghdad city near nuclear reactor at latitude N 33°11'41.3" E044°29'47.0" to N 33°11'46.1" E044°29'19.0" ,Hilla city from Al-Thawra Market at latitude N 30°30'21.5" E044°25'05.6" , Al-Rumaila area which is located at north of Basra city at latitude N 30°34'23.3" E047°21'02.4" and Karbalaa city from Al-Alawi Market at latitude N 32°37'02.7" E044°02'18.4"), as shown in Table ( 4.1)

All samples are cleansed with regular water and weighed as fresh (wet) for human consumption . After that, they are kept in a moisture-free oven for (1-10) days at 50°C to achieve a consistent weight and eliminate any humidity absorption before the radioactivity detection, After that ,the samples are electronically crushed by using an electric mill to ensure homogeneity (the loss ratio of samples when filtering is very low). To achieve a good homogeneity around the NaI (TI) detector, the weight of the samples is determined by using a digital weighing balance (a high-sensitivity digital weighing balance with a percent of 0.07 percent ; then, each sample is put in a nylon bag which is tagged with it's name ,weight and city name. Store for a month to achieve radiological balance. Fig (4.1 ) shows the research framework.



**Figure (4.1 ): Research Framework.**

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**Table (4.1) : Foods Categories Samples.**

No.	Name	Trade Name	Scientific Name	Code of Samples
1	Meat	Fish	Pisces	M1
		Chicken	Gallus gallus	M2
2	Vegetables	Cucumber	Cucumis sativus	V1
		Okra	Abelmoschus esculentus	V2
		Cayenne pepper	Capsicum annum	V3
		Sweet pepper	Capsicum annum	V4
		Eggplant	Solanum melongena	V5
		Cowpeas	Pumpkin	V6
3	Leafy Vegetables	Basil	Ocimum basilicum	L.V1
		Jew's mallow	Corchorus olitorius	L.V2
4	Fruits	Pomegranate	Punica granatum	F1
		Fig	Ficus carica	F2
		Orange	Citrus sinensis	F3
		Tangerine	Citrus reticulata	F4
		Pomelo	Citrus maxima	F5
		Bitter orange	Citrus aurantium	F6
5	Date	Khistawi Variet	Phoenix dactylifera	D1
		Zahdi Variety		D2
		Barben Variey		D3

### **4.2 Calibration of Gamma Spectrometer**

To conduct calibration spectrometry gamma, we must calibrate energy and then conduct calibration of efficiency.

#### **4.2.1 Energy Calibration for NaI(Tl) Detector**

The calibration of the detector enables us to find the linear relationship between the pulse coming out of the detector and the gamma energy falling on

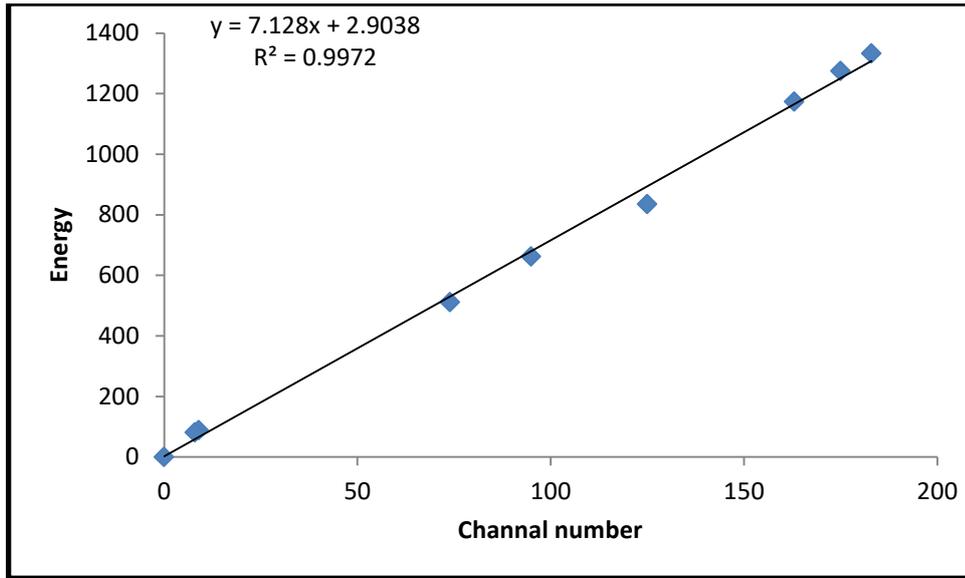
## **Chapter Four      Results, Discussion and Calculations**

the crystallization of the detector. The relationship between the channel number in the multichannel analyzer and the spectral line energy of the studied isotopes. The energy calibration of the NaI (Tl) spectroscopy system is established by measuring the position of selected full-energy gamma-ray peaks with large peak-height to background ratios, and whose energies are known precisely [82] .

An energy calibration for this detector is performed with a set of standard  $\gamma$ -ray sources from advance physics laboratory. In this way we can draw a straight calibration and then deduce the energy value of the isotopes as show in Table (4.2) and Fig.(4.2).

**Table (4.2): Energy and Channel Number for Standard Sources Used for Calibration.**

<b>Isotope</b>	<b>Energy (KeV)</b>	<b>Channel Number</b>
Co-60	1173.228	163
Co-60	1332.494	183
Mn-54	834.838	125
Cs-137	661.6	95
Na-22	511.006	74
Na-22	1274.5	175
Cd-109	88	9
Ba-133	81	8



**Figure (4.2): Energy Calibration Curve of NaI (TI) Detector.**

From the Fig. (4-2) we find the relation between the energy and channel number was represented by the following Equation :

$$E = 7.128 \text{ Ch} + 2.9038 \quad (4.1)$$

E: represent the Energy.

Ch: Chanal number.

### 4.2.2 Efficiency calibration

Calibration is intended to find a linear relation between the pulse emerging from the detector and energy gamma rays falling on the crystal capacity. It is used to calibrate the spectrum rays gamma standard sources of known energy and intensity the purpose of the multiplicity of sources is to get the spectrum of the energies used in the field of research. The researcher uses in his research this standard sources  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ ,  $^{54}\text{Mn}$ ,  $^{22}\text{Na}$ ,  $^{109}\text{Cd}$ ,  $^{133}\text{Ba}$ . Table (4.3) shows the potential of these elements and the intensity associated with each energy [83].

Definition of efficiency detector as the ratio between the number of photons of gamma rays falling upon the number of pulses emerging from it which is always less than 100%, which is necessary to know the accuracy and know the

## Chapter Four Results, Discussion and Calculations

following equation [84]:

$$\varepsilon = \frac{C}{A \cdot I_{\gamma} \cdot t} \times 100\% \quad (4.2)$$

C : Count (area under the photopeak after subtract Background Radiation).

t : Measurement time per second.

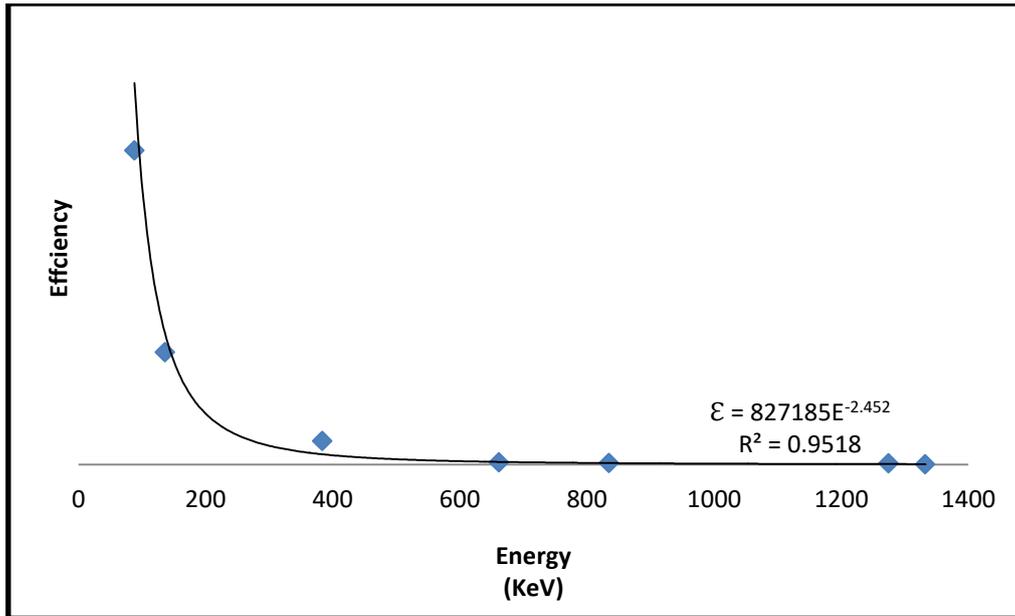
$I_{\gamma}$  :The percentage of the intensity of gamma rays emitted energy for each of the radioactive source energies .

A : Radioactivity (effectiveness) final measured by Becquerel irradiated at the time of the source (t), which is calculated from t Equation (2.10)

Calibration efficiency detector system sodium iodide doping with thallium NaI(Tl) used standard sources with energies known Table (4.2) were also used decay Equation (4.3) to measure radioactive final radioactive sources of activity, as the radioactivity is also registered by the detector for each energy from the energies of radioactive sources for a period of 500 seconds following this account measure efficiency ( $\varepsilon\%$ ) through the Equation (4.2) and Fig. (4.3) shows the relationship between energy efficiency and the standard sources used.

**Table(4.3): Standard Sources , Energies and Efficiency.**

No.	Source	Energy(KeV)	Efficiency%
1	Cd-109	88	11.639
2	Co-57	136.4	4.164
3	Ba-133	383.7	0.872
4	Cs-137	661.6	0.083
5	Mn-54	834.8	0.048
6	Na-22	1274.5	0.041
7	Co-60	1332.5	0.007



**Figure (4.3): The Relation between Efficiency and Energy.**

Through the Fig. (4.3) we find the relation between efficiency and energy which was represented by the following equation:

$$\epsilon = 827185 E^{-2.452} \quad (4-3)$$

$\epsilon$ : represent the Efficiency.

E: represent the Energy.

### 4.3 Specific Activity Measurements

The gamma spectra of the collected samples as shown in Table (4.1) was measured and the activities of  $^{238}\text{U}$  series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$  in each sample were determined by measuring the characteristic gamma-peaks of their daughters. Table (4.4) illustrates that and shows the energy and intensity associated radionuclides and efficiency at each energy.

**Table(4.4): Radionuclides Now in Research and Energy and Intensity Associated Efficiency.**

Radionuclides	Energy (KeV)	$I_{\gamma}$	Efficiency %
$^{40}\text{K}$	1460	0.106	0.01440
$^{214}\text{Bi}$	1764	0.170	0.090612
$^{208}\text{Tl}$	2614	0.360	0.034543

After detecting for samples by the sodium iodide detector and using Equations (2.12 ) we obtain the following results :

## Chapter Four Results, Discussion and Calculations

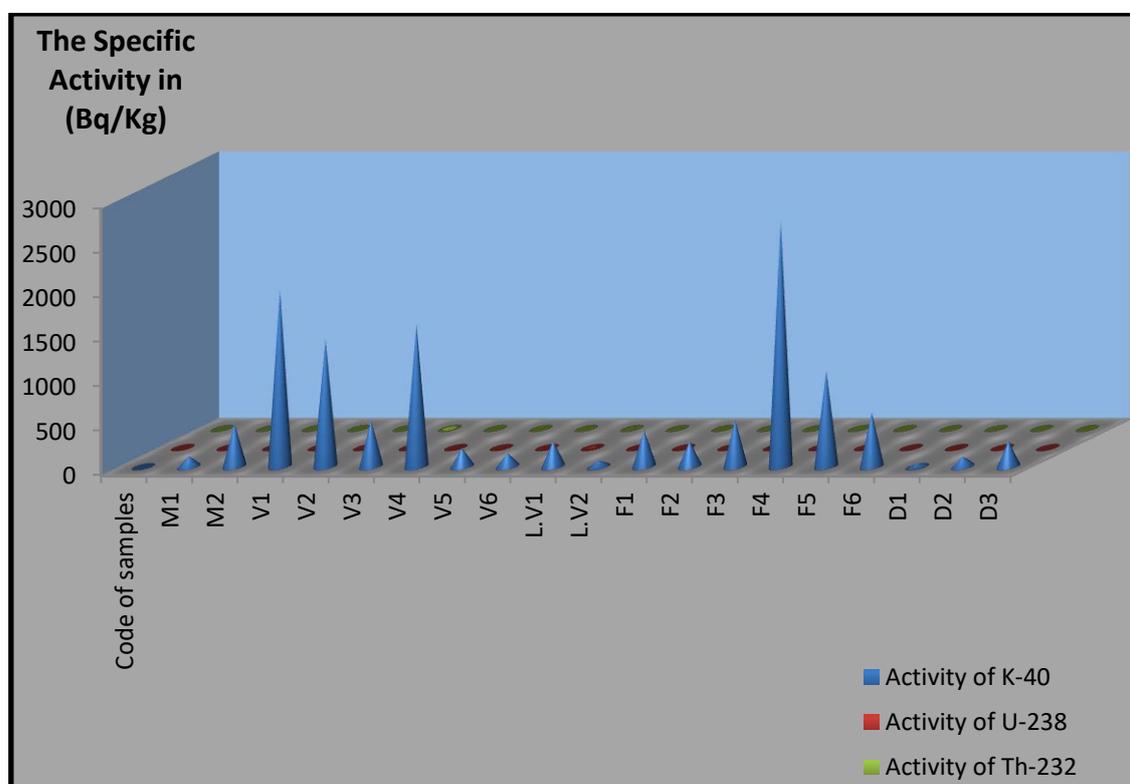
The specific activity value of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in food for 19 samples are collected from Al-Tuwaitha village which is located at southeast of Baghdad with an average of  $^{238}\text{U}$   $0.890 \pm 0.146$  Bq/Kg ,for range  $0.038 \pm 0.022$  Bq/Kg to  $3.606 \pm 0.585$  Bq/Kg ,the average of  $^{232}\text{Th}$   $1.378 \pm 0.176$  Bq/Kg with a range  $0.063 \pm 0.031$  Bq/Kg to  $5.984 \pm 0.710$  Bq/Kg . The specific activity of  $^{238}\text{U}$  and  $^{232}\text{Th}$  within the allowed limit. The average of  $^{40}\text{K}$   $683.923 \pm 12.025$  Bq/Kg from  $36.396 \pm 2.171$  Bq/Kg to  $2757.032 \pm 27.280$  Bq/Kg. The specific activity of  $^{40}\text{K}$  values are higher than worldwide median value in (chicken, cucumber , okra , cayenne pepper , sweet pepper, pomegranate ,orang, tangerine, pomelo and bitter orange) as shown in Table (4.5) and Fig. (4.4)

**Table (4.5): The Specific Activity of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for Food Samples from Al-Tuwaitha Village , Baghdad.**

No.	Code of Samples	Country	Specific Activity (Bq/Kg)		
			$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$
1	M1	Iraq	$0.688 \pm 0.106$	$0.284 \pm 0.075$	$119.115 \pm 4.439$
2	M2	Iraq	$2.488 \pm 0.186$	$0.727 \pm 0.112$	<b><math>489.800 \pm 8.312</math></b>
3	V1	Iraq	$0.632 \pm 0.153$	$1.750 \pm 0.283$	<b><math>1983.419 \pm 27.280</math></b>
4	V2	Iraq	$0.901 \pm 0.144$	$0.744 \pm 0.146$	<b><math>1430.661 \pm 18.269</math></b>
5	V3	Iraq	$0.027 \pm 0.136$	$5.984 \pm 0.710$	<b><math>526.031 \pm 19.006</math></b>
6	V4	Iraq	$1.45 \pm 0.245$	$0.924 \pm 0.217$	<b><math>1602.699 \pm 25.893</math></b>
7	V5	Iraq	$0.816 \pm 0.124$	$0.211 \pm 0.070$	$211.482 \pm 6.364$
8	V6	Iraq	$0.454 \pm 0.117$	$1.651 \pm 0.249$	$155.373 \pm 6.893$
9	L.V1	Iraq	$3.606 \pm 0.585$	$2.468 \pm 0.538$	$289.256 \pm 16.644$
10	L.V2	Iraq	$0.801 \pm 0.032$	$0.728 \pm 0.109$	$68.748 \pm 3.044$
11	F1	Iraq	$0.792 \pm 0.104$	$0.372 \pm 0.079$	<b><math>407.667 \pm 7.496</math></b>
12	F2	Iraq	$0.839 \pm 0.203$	$0.428 \pm 0.161$	$286.684 \pm 11.955$
13	F3	Iraq	$0.605 \pm 0.121$	$0.659 \pm 0.140$	<b><math>532.512 \pm 11.405</math></b>
14	F4	Iraq	$0.877 \pm 0.146$	$0.090 \pm 0.052$	<b><math>2757.032 \pm 26.038</math></b>

## Chapter Four Results, Discussion and Calculations

15	F5	Iraq	$1.378 \pm 0.177$	$0.853 \pm 0.155$	<b><math>1079.375 \pm 15.818</math></b>
16	F6	Iraq	$0.269 \pm 0.060$	$0.266 \pm 0.066$	<b><math>611.542 \pm 9.113</math></b>
17	D1	Iraq	$0.038 \pm 0.022$	$0.063 \pm 0.031$	$36.396 \pm 2.171$
18	D2	Iraq	$0.349 \pm 0.052$	$0.481 \pm 0.068$	$117.425 \pm 3.034$
19	D3	Iraq	$0.385 \pm 0.052$	$0.453 \pm 0.073$	$289.322 \pm 5.306$
Av.			$0.890 \pm 0.146$	$1.378 \pm 0.176$	$683.923 \pm 12.025$
Min.			$0.038 \pm 0.022$	$0.063 \pm 0.031$	$36.396 \pm 2.171$
Max.			$3.606 \pm 0.585$	$5.984 \pm 0.710$	$2757.032 \pm 26.038$
World Wide Median Value [85]			35	30	400



**Figure (4.4): The Specific Activity in (Bq/Kg) of ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$ ) for Food Samples from Al-Tuwaitha Village, Baghdad.**

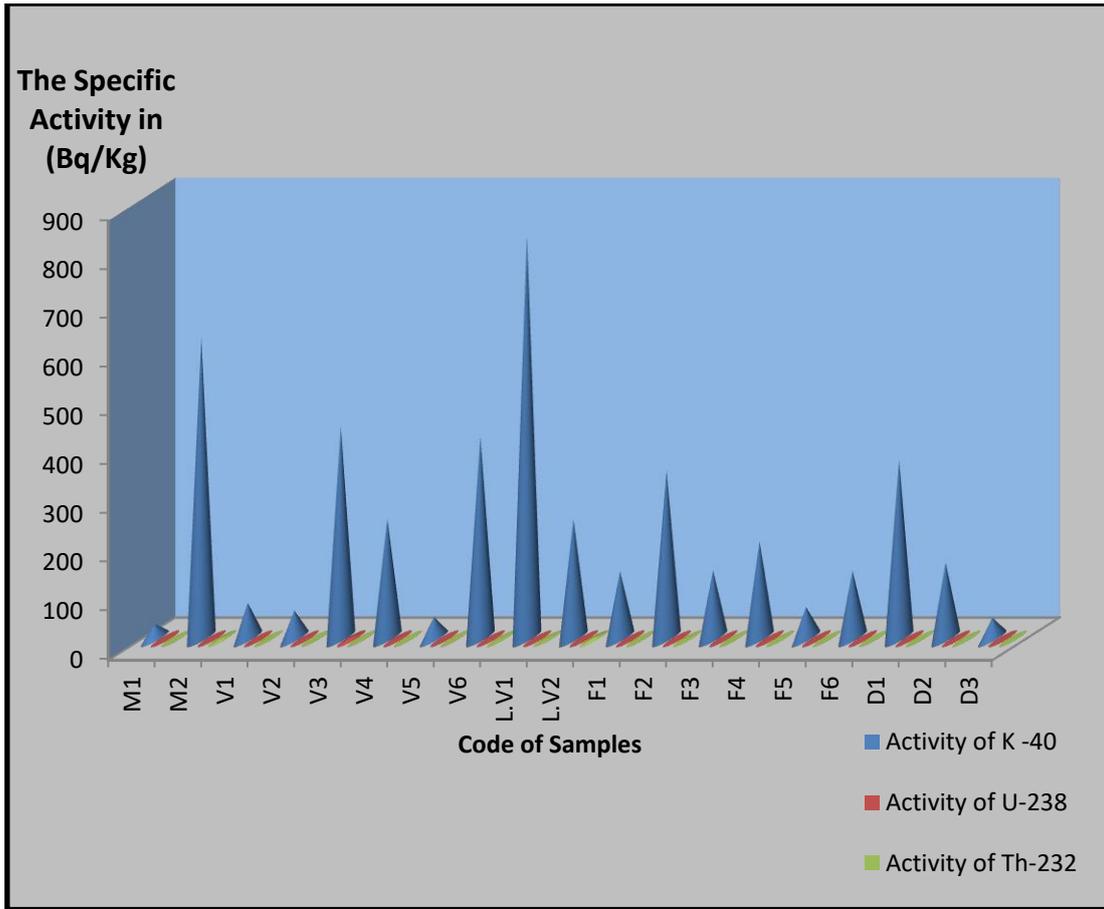
The results shown in Table (4.6) and Fig.(4.5) explain the specific activity value of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in food for 19 samples are collected from Hilla city with an average of  $^{238}\text{U}$   $0.374 \pm 0.055$  Bq/Kg, for range  $0.007 \pm 0.005$  Bq/Kg to  $2.797 \pm 0.453$  Bq/Kg, the average of  $^{232}\text{Th}$   $0.374 \pm 0.119$  Bq/Kg with a range  $0.040 \pm 0.028$  Bq/Kg to  $3.226 \pm 0.447$  Bq/Kg. The specific activity of

## Chapter Four Results, Discussion and Calculations

$^{238}\text{U}$  and  $^{232}\text{Th}$  within the allowed limit. The average of  $^{40}\text{K}$   $241.629 \pm 8.132$  Bq/Kg from  $30.033 \pm 0.061$  Bq/Kg to  $825.795 \pm 25.843$  Bq/Kg. The specific activity of  $^{40}\text{K}$  values are higher than worldwide median value in (chicken, cayenne pepper, cowpeas and basil).

**Table (4.6): The Specific Activity of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for Food Samples from Hilla city.**

No.	Code of Samples	Country	Specific Activity (Bq/Kg)		
			$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$
1	M1	Iraq	$0.151 \pm 0.061$	$0.124 \pm 0.062$	$30.033 \pm 0.0617$
2	M2	Iraq	$0.619 \pm 0.150$	$2.166 \pm 0.312$	<b><math>617.269 \pm 15.064</math></b>
3	V1	Iraq	$0.031 \pm 0.011$	$0.299 \pm 0.038$	$74.289 \pm 1.710$
4	V2	Iraq	$0.338 \pm 0.035$	$0.054 \pm 0.015$	$57.937 \pm 1.466$
5	V3	Iraq	$2.796 \pm 0.453$	$0.182 \pm 0.128$	<b><math>435.2719 \pm 17.980</math></b>
6	V4	Iraq	$0.618 \pm 0.178$	$0.063 \pm 0.063$	$246.456 \pm 11.320$
7	V5	Iraq	$0.007 \pm 0.005$	$0.068 \pm 0.017$	$44.678 \pm 1.288$
8	V6	Iraq	$0.519 \pm 0.126$	$0.681 \pm 0.160$	<b><math>415.166 \pm 11.316</math></b>
9	L.V1	Iraq	$0.160 \pm 0.113$	$0.992 \pm 0.313$	<b><math>825.795 \pm 25.843</math></b>
10	L.V2	Egypt	$0.200 \pm 0.100$	$3.226 \pm 0.447$	$245.676 \pm 11.144$
11	F1	Iraq	$0.164 \pm 0.047$	$0.373 \pm 0.079$	$138.804 \pm 4.382$
12	F2	Iraq	$0.037 \pm 0.026$	$0.705 \pm 0.128$	$345.574 \pm 8.136$
13	F3	Iraq	$0.273 \pm 0.068$	$0.127 \pm 0.051$	$140.928 \pm 4.930$
14	F4	Iraq	$0.097 \pm 0.048$	$0.362 \pm 0.104$	$200.180 \pm 7.016$
15	F5	Iraq	$0.075 \pm 0.037$	$0.093 \pm 0.046$	$65.170 \pm 3.524$
16	F6	Iraq	$0.242 \pm 0.062$	$0.040 \pm 0.028$	$139.873 \pm 4.777$
17	D1	Iraq	$0.304 \pm 0.124$	$0.188 \pm 0.108$	$367.553 \pm 13.726$
18	D2	Iraq	$0.300 \pm 0.075$	$0.232 \pm 0.073$	$156.580 \pm 5.448$
19	D3	Iraq	$0.167 \pm 0.055$	$0.368 \pm 0.092$	$43.713 \pm 2.863$
Av.			$0.374 \pm 0.055$	$0.374 \pm 0.119$	$241.629 \pm 8.142$
Min.			$0.007 \pm 0.005$	$0.040 \pm 0.028$	$30.033 \pm 0.061$
Max.			$2.796 \pm 0.453$	$3.226 \pm 0.447$	$825.795 \pm 25.843$
World Wide Median Value [85]			35	30	400



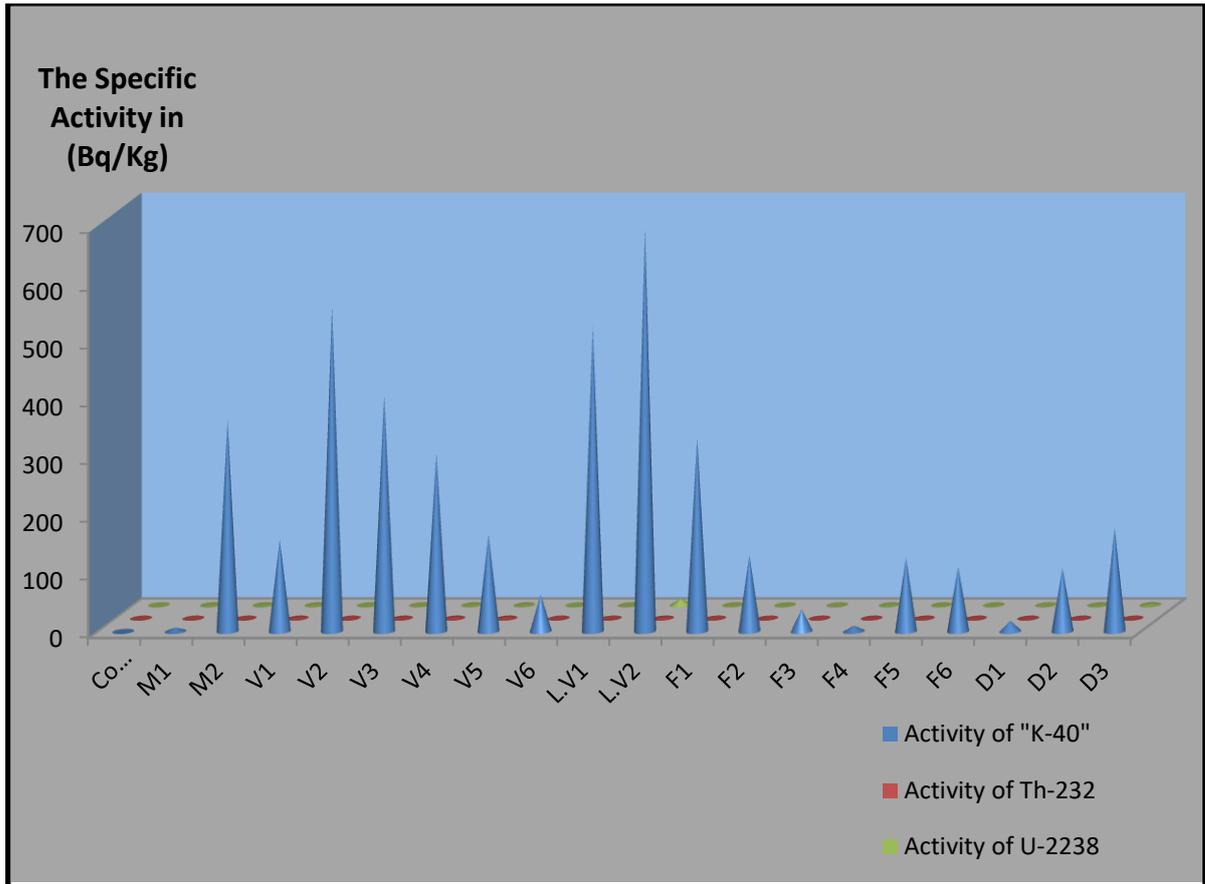
**Figure (4.5): The Specific Activity in (Bq/Kg) of ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$ ) for Food Samples from Hilla city.**

Table (4.7) and Fig.(4.6) display the specific activity value of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in food for 19 samples are collected from Al-Rumaila area which is located at north of Basra city with an average of  $^{238}\text{U}$   $0.648 \pm 0.211$  Bq/Kg , for range  $0.058 \pm 0.030$  Bq/Kg to  $2.031 \pm 0.522$  Bq/Kg ,the average of  $^{232}\text{Th}$   $1.145 \pm 0.178$  Bq/Kg with a range  $0.032 \pm 0.032$  Bq/Kg to  $10.502 \pm 0.907$  Bq/Kg . The specific activity of  $^{238}\text{U}$  and  $^{232}\text{Th}$  within the allowed limit. The average of  $^{40}\text{K}$   $229.041 \pm 7.742$  Bq/Kg from  $6.896 \pm 1.625$  Bq/Kg to  $697.279 \pm 21.100$  Bq/Kg. The specific activity of  $^{40}\text{K}$  values is higher than worldwide median value in (okra, cayenne pepper , basil and jew's mallow) .

## Chapter Four Results, Discussion and Calculations

**Table (4.7): The Specific Activity of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for Food Samples from Rumaila Area, Basra.**

No.	Code of Samples	Country	Specific Activity (Bq/Kg)		
			$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$
1	M1	Iraq	$0.075 \pm 0.085$	$0.846 \pm 0.199$	$6.896 \pm 1.625$
2	M2	Iraq	$0.751 \pm 0.068$	$0.744 \pm 0.151$	$367.755 \pm 9.641$
3	V1	Iraq	$1.452 \pm 0.428$	$1.116 \pm 0.263$	$160.245 \pm 9.000$
4	V2	Iraq	$0.115 \pm 0.074$	$0.237 \pm 0.075$	<b><math>563.757 \pm 10.447</math></b>
5	V3	Iraq	$0.554 \pm 0.278$	$0.137 \pm 0.097$	<b><math>410.440 \pm 15.159</math></b>
6	V4	Iraq	$2.003 \pm 0.474$	$1.268 \pm 0.264$	$310.043 \pm 11.803$
7	V5	Iraq	$2.031 \pm 0.510$	$1.258 \pm 0.281$	$169.166 \pm 9.312$
8	V6	Iraq	$0.058 \pm 0.031$	$0.104 \pm 0.029$	$64.792 \pm 2.061$
9	L.V1	Iraq	$0.127 \pm 0.116$	$0.262 \pm 0.117$	<b><math>528.757 \pm 15.047</math></b>
10	L.V2	Egypt	$1.708 \pm 0.522$	$10.502 \pm 0.907$	<b><math>697.279 \pm 21.100</math></b>
11	F1	Iraq	$0.318 \pm 0.126$	$0.518 \pm 0.113$	$336.818 \pm 8.229$
12	F2	Iraq	$0.140 \pm 0.070$	$0.086 \pm 0.038$	$133.406 \pm 4.346$
13	F3	Iraq	$0.424 \pm 0.168$	$0.032 \pm 0.032$	$39.072 \pm 3.233$
14	F4	Iraq	$0.740 \pm 0.245$	$0.797 \pm 0.178$	$10.074 \pm 1.809$
15	F5	Iraq	$1.130 \pm 0.277$	$0.366 \pm 0.110$	$129.288 \pm 5.925$
16	F6	Iraq	$0.267 \pm 0.134$	$0.397 \pm 0.114$	$113.772 \pm 5.538$
17	D1	Iraq	$0.560 \pm 0.177$	$0.083 \pm 0.048$	$18.763 \pm 2.059$
18	D2	Iraq	$0.393 \pm 0.127$	$0.731 \pm 0.121$	$110.347 \pm 4.272$
19	D3	Iraq	$0.138 \pm 0.089$	$2.262 \pm 0.254$	$181.049 \pm 6.499$
Av.			$0.648 \pm 0.211$	$1.145 \pm 0.178$	$229.041 \pm 7.742$
Min.			$0.058 \pm 0.030$	$0.032 \pm 0.032$	$6.896 \pm 1.625$
Max.			$2.031 \pm 0.522$	$10.502 \pm 0.907$	$697.279 \pm 21.100$
World Wide Median Value [85]			35	30	400



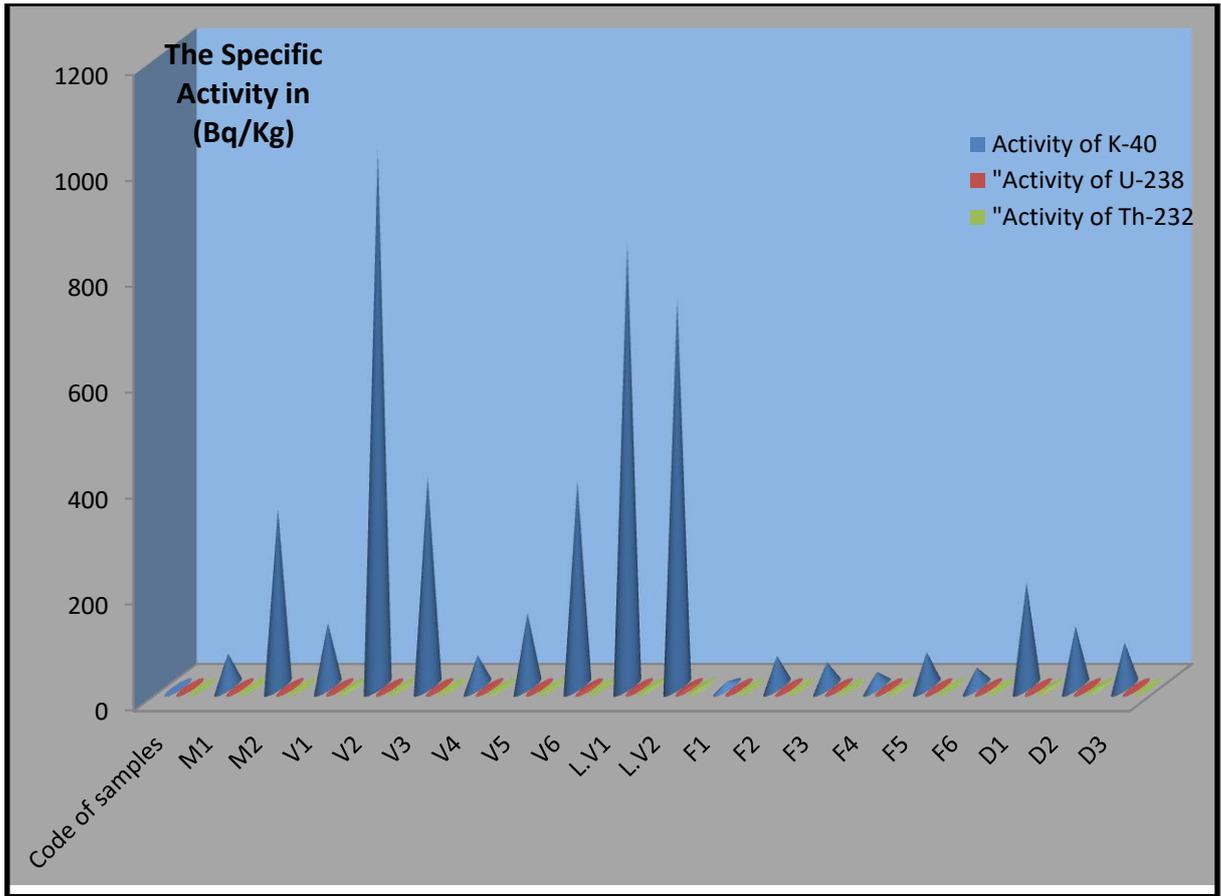
**Figure (4.6): The Specific Activity in (Bq/Kg) of (<sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K ) for Food Samples from Rumaila Area, Basra.**

Table (4.8) and Fig.(4.7) show the specific activity value of <sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K in food for 19 samples are collected from Karbalaa city with an average of <sup>238</sup>U  $0.615 \pm 0.139$  Bq/Kg ,for range  $0.039 \pm 0.028$  Bq/Kg to  $2.060 \pm 0.364$  Bq/Kg ,the average of <sup>232</sup>Th  $0.538 \pm 0.144$  Bq/Kg with a range  $0.094 \pm 0.039$  Bq/Kg to  $1.316 \pm 0.298$  Bq/Kg . The specific activity of <sup>238</sup>U and <sup>232</sup>Th within the allowed limit. The average of <sup>40</sup>K  $250.180 \pm 8.746$  Bq/Kg from  $11.598 \pm 1.523$  Bq/Kg to  $1014.644 \pm 27.452$  Bq/Kg. The specific activity of <sup>40</sup>K values are higher than worldwide median value in (okra, basil and jew's mallow) .

## Chapter Four Results, Discussion and Calculations

**Table (4.8): The Specific Activity of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  for Food Samples from Karbala city.**

No.	Code of Samples	Country	Specific Activity (Bq/Kg)		
			$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$
1	M1	Iraq	$0.534 \pm 0.133$	$0.165 \pm 0.082$	$64.367 \pm 4.657$
2	M2	Iraq	$0.596 \pm 0.130$	$0.105 \pm 0.060$	$337.598 \pm 9.836$
3	V1	Iraq	$0.524 \pm 0.185$	$1.055 \pm 0.292$	$122.424 \pm 9.000$
4	V2	Iraq	$0.662 \pm 0.220$	$0.547 \pm 0.223$	<b><math>1014.644 \pm 27.452</math></b>
5	V3	Iraq	$0.538 \pm 0.170$	$0.133 \pm 0.094$	$398.188 \pm 14.707$
6	V4	Iraq	$0.888 \pm 0.215$	$0.712 \pm 0.214$	$61.188 \pm 5.681$
7	V5	Iraq	$0.203 \pm 0.101$	$0.566 \pm 0.188$	$140.972 \pm 8.500$
8	V6	Iraq	$1.727 \pm 0.209$	$0.094 \pm 0.054$	$390.364 \pm 10.002$
9	L.V1	Iraq	$0.711 \pm 0.190$	$1.132 \pm 0.266$	<b><math>837.118 \pm 20.715</math></b>
10	L.V2	Egypt	$2.060 \pm 0.364$	$1.116 \pm 0.298$	<b><math>732.478 \pm 21.818</math></b>
11	F1	Iraq	$0.039 \pm 0.028$	$0.368 \pm 0.095$	$11.598 \pm 1.523$
12	F2	Iraq	$0.437 \pm 0.106$	$0.095 \pm 0.055$	$59.794 \pm 3.942$
13	F3	Iraq	$1.181 \pm 0.189$	$0.375 \pm 0.118$	$48.324 \pm 3.844$
14	F4	Iraq	$0.716 \pm 0.124$	$0.834 \pm 0.149$	$29.380 \pm 2.538$
15	F5	Iraq	$0.049 \pm 0.034$	$0.182 \pm 0.074$	$66.850 \pm 4.068$
16	F6	Iraq	$0.447 \pm 0.115$	$0.221 \pm 0.090$	$37.900 \pm 3.376$
17	D1	Iraq	$0.091 \pm 0.045$	$1.109 \pm 0.177$	$199.137 \pm 6.794$
18	D2	Iraq	$0.087 \pm 0.038$	$1.316 \pm 0.168$	$116.046 \pm 4.517$
19	D3	Iraq	$0.192 \pm 0.048$	$0.104 \pm 0.039$	$85.046 \pm 3.212$
Av.			$0.615 \pm 0.139$	$0.538 \pm 0.144$	$250.180 \pm 8.746$
Min.			$0.039 \pm 0.028$	$0.094 \pm 0.039$	$11.598 \pm 1.523$
Max.			$2.060 \pm 0.364$	$1.316 \pm 0.298$	$1014.644 \pm 27.452$
World Wide Median Value [85]			35	30	400



**Figure (4.7): The Specific Activity in (Bq/Kg) of (<sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K ) for Food Samples from Karbala city.**

#### 4.4 Radiation Hazard Calculation

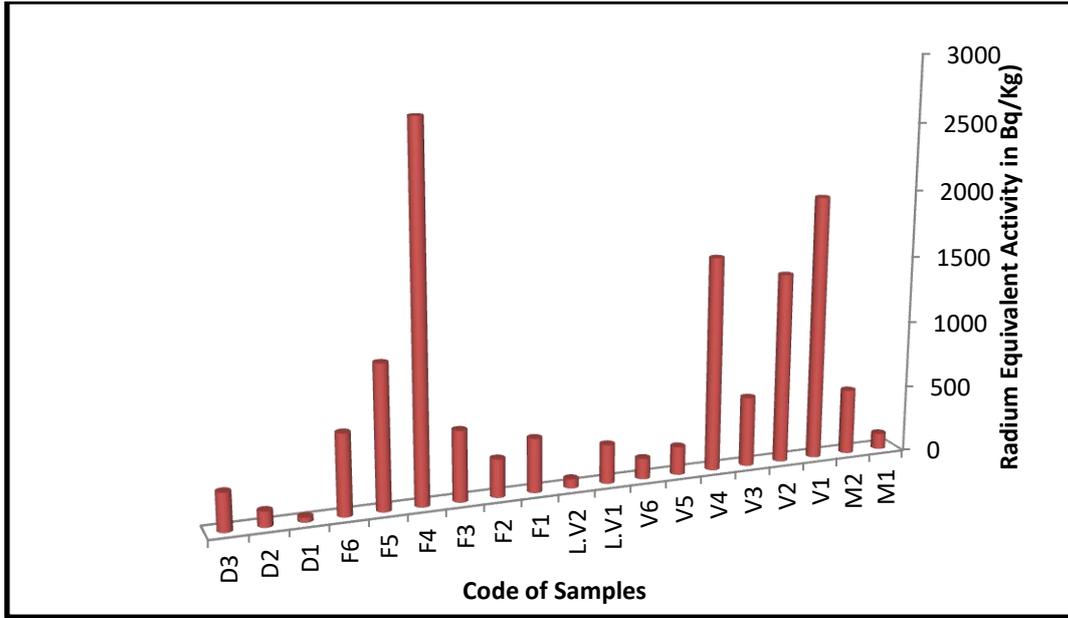
The level of health risks which consumers of the food analysed in the study, the radium equivalent was calculated from the Equations (2.15), (2.13) and (2.16) in the second chapter presented of food samples from Al-Tuwaitha village, Baghdad as shown in Table (4.9) and Fig.(4.8) with an average  $19.921 \pm 28.683$  Bq/Kg ,for range  $1.817 \pm 2.804$  Bq/Kg to  $70.417 \pm 101.644$  Bq/Kg; the radium equivalent values within the allowed limit worldwide median value 370 Bq/Kg ,the average of absorbed dose rate values which are  $9.018 \pm 0.423$  nGy/h with a range  $0.848 \pm 0.201$  nGy/h to  $36.387 \pm 1.191$  nGy/h so the absorbed dose rate within the allowed limit worldwide median value 55 nGy/h as seen in Fig. (4.9), the average of Internal radiation hazard value is  $0.055 \pm 0.003$  Bq/Kg with a range  $0.005 \pm 0.001$  Bq/Kg to  $0.194 \pm 0.010$  Bq/Kg, so all

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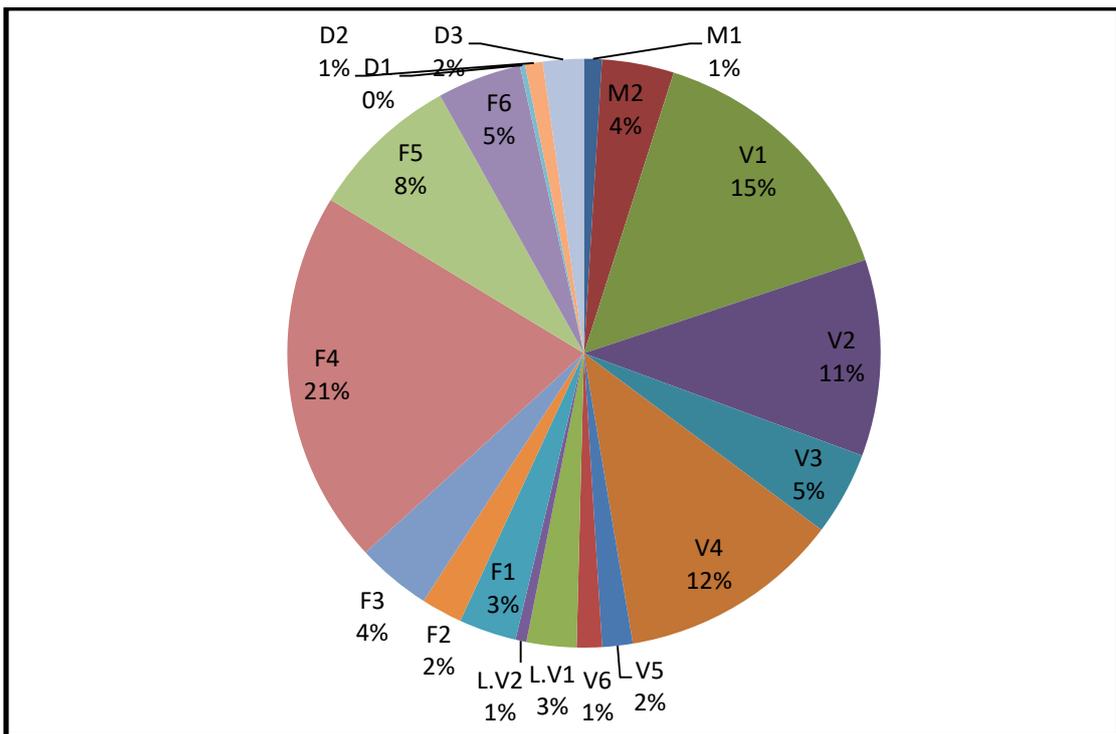
samples within the allowed limit that is less than one as shown in Fig.(4.10) .

**Table (4.9): Radium Equivalent , Absorbed Dose Rate and Internal Radiation Hazard of Food Samples from Al-Tuwaitha Village, Baghdad**

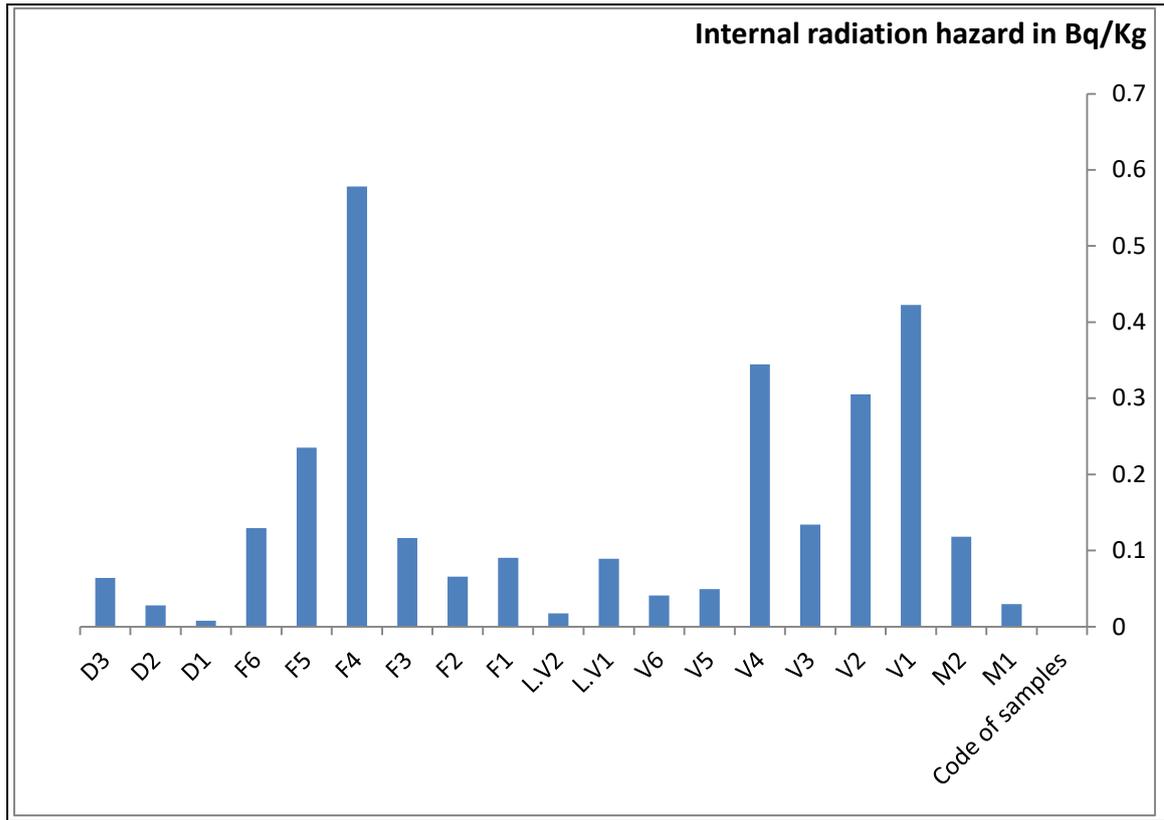
No.	Code of Samples	Radium Equivalent (Ra <sub>eq</sub> ) (Bq/kg)	Absorbed Dose Rate (AD) (nGy/h)	Internal Radiation Hazard (H <sub>in</sub> ) (Bq/kg)
1	M1	120.122 ± 4.596	5.461 ± 0.281	0.029 ± 0.0017
2	M2	<b>493.414 ± 8.577</b>	22.025 ± 0.502	0.118 ± 0.003
3	V1	<b>1984.458 ± 27.521</b>	<b>84.087 ± 1.384</b>	0.422 ± 0.007
4	V2	<b>1432.008 ± 18.487</b>	<b>60.537 ± 0.919</b>	0.305 ± 0.005
5	V3	<b>526.881 ± 19.255</b>	25.777 ± 1.296	0.133 ± 0.007
6	V4	<b>1604.845 ± 26.261</b>	<b>68.077 ± 1.328</b>	0.344 ± 0.007
7	V5	212.666 ± 6.548	9.327 ± 0.366	0.049 ± 0.002
8	V6	156.150 ± 7.080	7.714 ± 0.496	0.041 ± 0.003
9	L.V1	294.603 ± 17.522	15.261 ± 1.298	0.089 ± 0.008
10	L.V2	68.919 ± 3.099	3.355 ± 0.210	0.017 ± 0.001
11	F1	<b>408.829 ± 7.651</b>	17.597 ± 0.409	0.090 ± 0.002
12	F2	287.918 ± 12.259	12.608 ± 0.693	0.065 ± 0.004
13	F3	<b>533.428 ± 11.589</b>	22.894 ± 0.618	0.116 ± 0.003
14	F4	<b>2758.293 ± 26.251</b>	<b>115.429 ± 1.185</b>	0.578 ± 0.006
15	F5	<b>1081.412 ± 16.084</b>	46.176 ± 0.838	0.235 ± 0.004
16	F6	<b>611.946 ± 9.204</b>	25.791 ± 0.449	0.129 ± 0.002
17	D1	36.456 ± 2.205	1.575 ± 0.120	0.008 ± 0.001
18	D2	117.947 ± 3.114	5.357 ± 0.192	0.028 ± 0.001
19	D3	289.909 ± 5.399	12.524 ± 0.295	0.063 ± 0.001
Av.		685.275 ± 12.248	29.556 ± 0.678	0.150 ± 0.003
Min.		36.456 ± 2.205	1.575 ± 0.120	0.008 ± 0.001
Max.		2758.293 ± 26.251	115.429 ± 1.185	0.578 ± 0.006
World Wide Median Value		> 370[86]	55 [87]	>1[86]



**Figure (4.8): Radium Equivalent Activity in (Bq/Kg) of Food Samples from Al-Tuwaitha Village, Baghdad.**



**Figure (4.9): Absorbed Dose Rate in (nGy/h) of Food Samples from Al-Tuwaitha Village, Baghdad.**



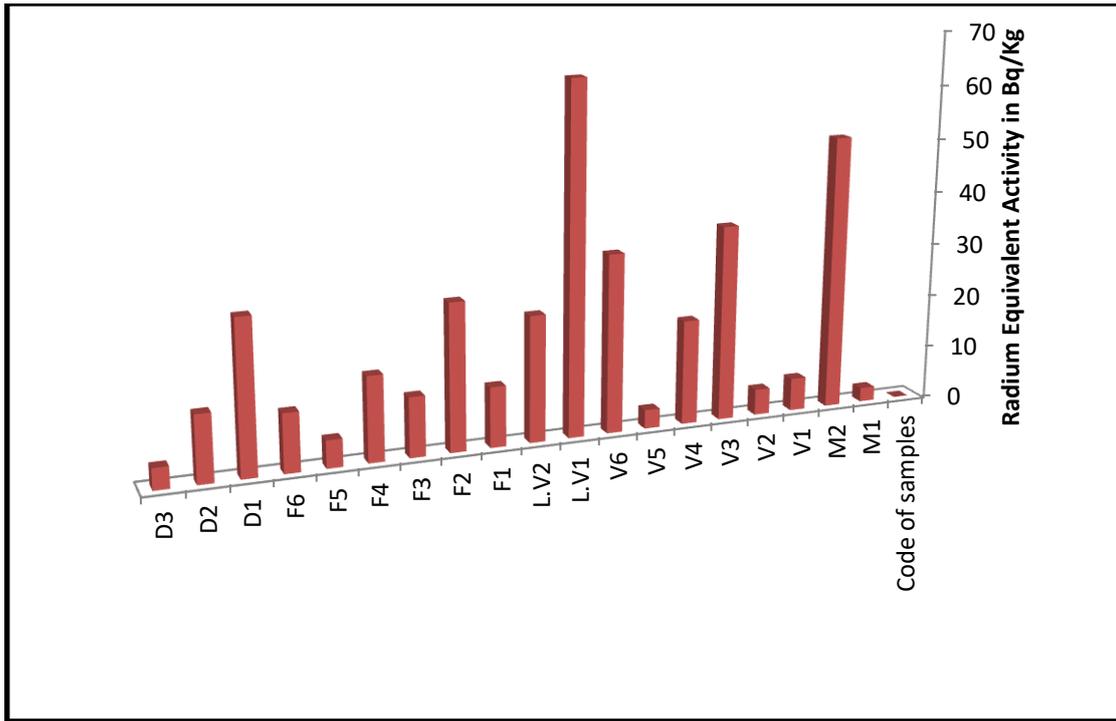
**Figure (4.10): Internal Radiation Hazard in (Bq/Kg) of Food Samples from Al-Tuwaitha Village, Baghdad.**

Table (4.10) and Fig.(4.11) show radium equivalent values of food samples from Hilla city with an average  $19.758 \pm 0.892$  Bq/Kg, for range  $2.642 \pm 0.364$  Bq/Kg to  $65.166 \pm 2.552$  Bq/Kg; the radium equivalent values within the allowed limit worldwide median value 370 Bq/Kg, the average of absorbed dose rate values which are  $10.587 \pm 0.457$  nGy/h with a range  $1.399 \pm 0.182$  nGy/h to  $35.126 \pm 1.325$  nGy/h so the absorbed dose rate within the allowed limit worldwide median value 55 nGy/h as seen in Fig.(4.12), the average of Internal radiation hazard value is  $0.054 \pm 0.002$  Bq/Kg with a range  $0.007 \pm 0.001$  Bq/Kg to  $0.176 \pm 0.007$  Bq/Kg , so all samples within the allowed limit less than one as shown in Fig. (4.13) .

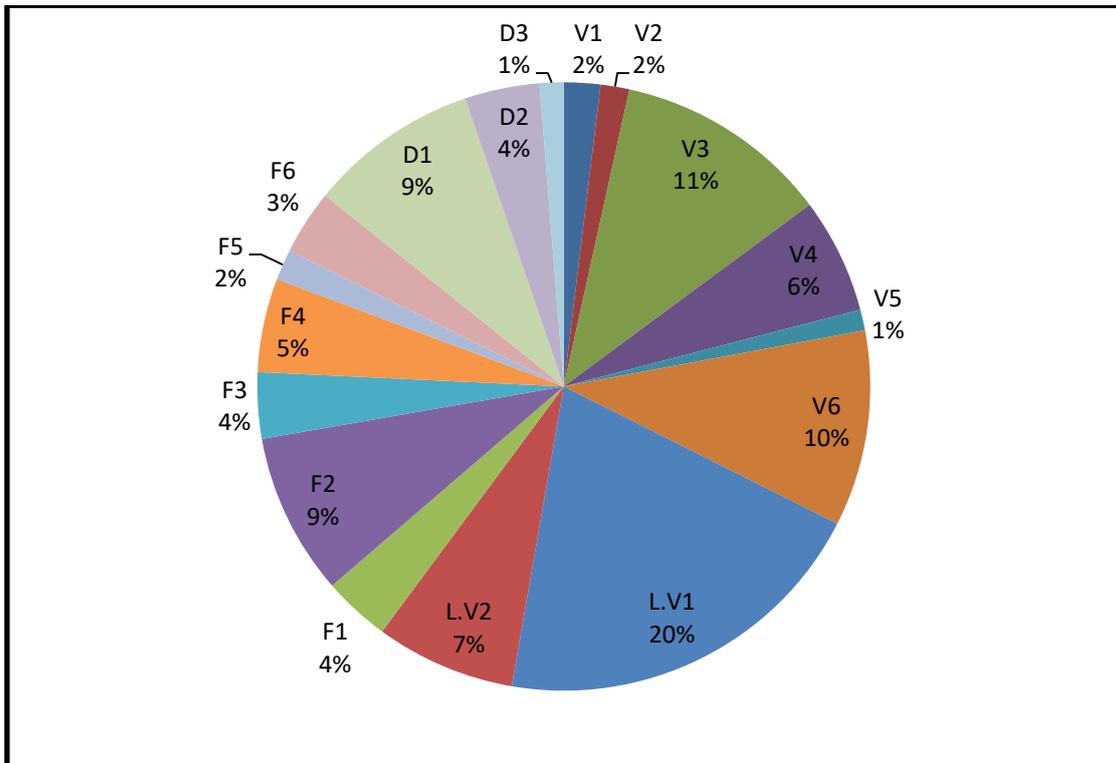
## Chapter Four      Results, Discussion and Calculations

**Table (4.10): Radium Equivalent , Absorbed Dose Rate and Internal Radiation Hazard of Food Samples from Hilla City.**

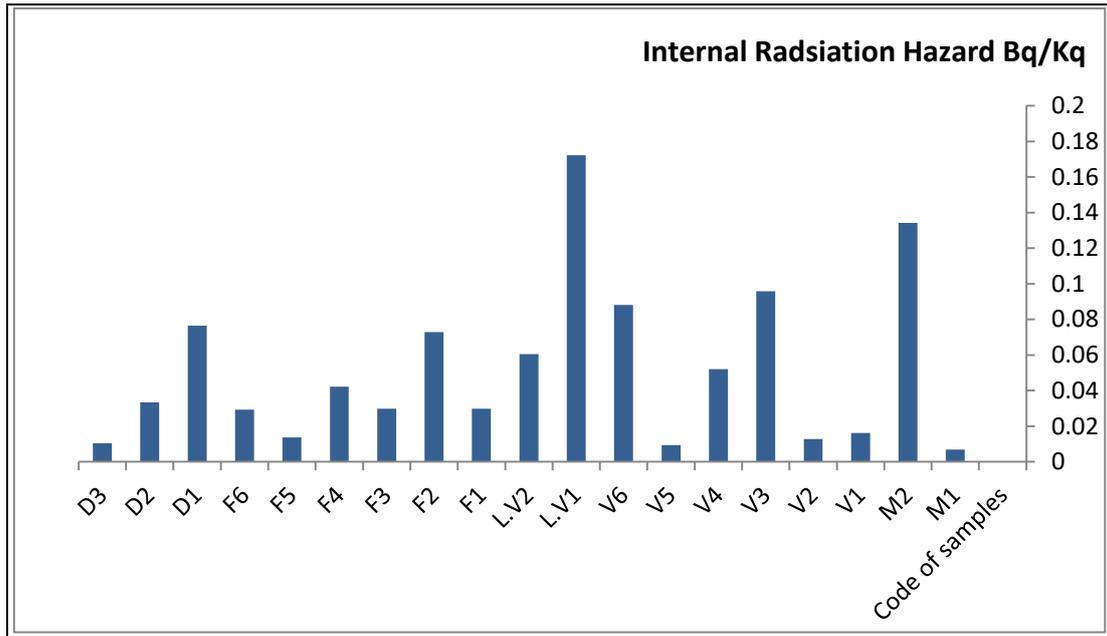
No.	Code of Samples	Radium equivalent ( $Ra_{eq}$ ) (Bq/kg)	Absorbed dose rate (AD) (nGy/h)	Internal radiation hazard ( $H_{in}$ ) (Bq/kg)
1	M1	$2.642 \pm 0.364$	$1.399 \pm 0.182$	$0.007 \pm 0.001$
2	M2	$51.246 \pm 1.757$	$27.371 \pm 0.891$	$0.140 \pm 0.005$
3	V1	$6.180 \pm 0.197$	$3.298 \pm 0.1000$	$0.0167 \pm 0.001$
4	V2	$4.877 \pm 0.170$	$2.606 \pm 0.087$	$0.014 \pm 0.001$
5	V3	$36.573 \pm 2.022$	$19.556 \pm 1.039$	$0.106 \pm 0.006$
6	V4	$19.686 \pm 1.141$	$10.602 \pm 0.594$	$0.054 \pm 0.003$
7	V5	$3.545 \pm 0.129$	$1.908 \pm 0.067$	$0.009 \pm 0.001$
8	V6	$33.461 \pm 1.227$	$17.975 \pm 0.629$	$0.091 \pm 0.003$
9	L.V1	$65.166 \pm 2.552$	$35.126 \pm 1.325$	$0.176 \pm 0.007$
10	L.V2	$23.731 \pm 1.598$	$12.340 \pm 0.788$	$0.064 \pm 0.004$
11	F1	$11.386 \pm 0.498$	$6.096 \pm 0.254$	$0.031 \pm 0.001$
12	F2	$27.655 \pm 0.837$	$14.866 \pm 0.431$	$0.074 \pm 0.002$
13	F3	$11.306 \pm 0.522$	$6.081 \pm 0.269$	$0.031 \pm 0.001$
14	F4	$16.029 \pm 0.738$	$8.617 \pm 0.380$	$0.043 \pm 0.002$
15	F5	$5.227 \pm 0.376$	$2.810 \pm 0.193$	$0.014 \pm 0.001$
16	F6	$11.070 \pm 0.471$	$5.969 \pm 0.245$	$0.030 \pm 0.001$
17	D1	$28.876 \pm 1.337$	$15.584 \pm 0.697$	$0.078 \pm 0.003$
18	D2	$12.689 \pm 0.599$	$6.812 \pm 0.307$	$0.035 \pm 0.001$
19	D3	$4.060 \pm 0.408$	$2.128 \pm 0.202$	$0.011 \pm 0.001$
Av.		$19.758 \pm 0.892$	$10.587 \pm 0.457$	$0.054 \pm 0.002$
Min.		$2.642 \pm 0.364$	$1.399 \pm 0.182$	$0.007 \pm 0.001$
Max.		$65.166 \pm 2.552$	$35.126 \pm 1.325$	$0.176 \pm 0.007$
World Wide Median Value		$> 370[86]$	$55[87]$	$>1[86]$



**Figure (4.11):Radium Equivalent Activity in (Bq/Kg) of Food Samples from Hilla City.**



**Figure (4.12): Absorbed Dose Rate in (nGy/h) of Food Samples from Hilla City.**



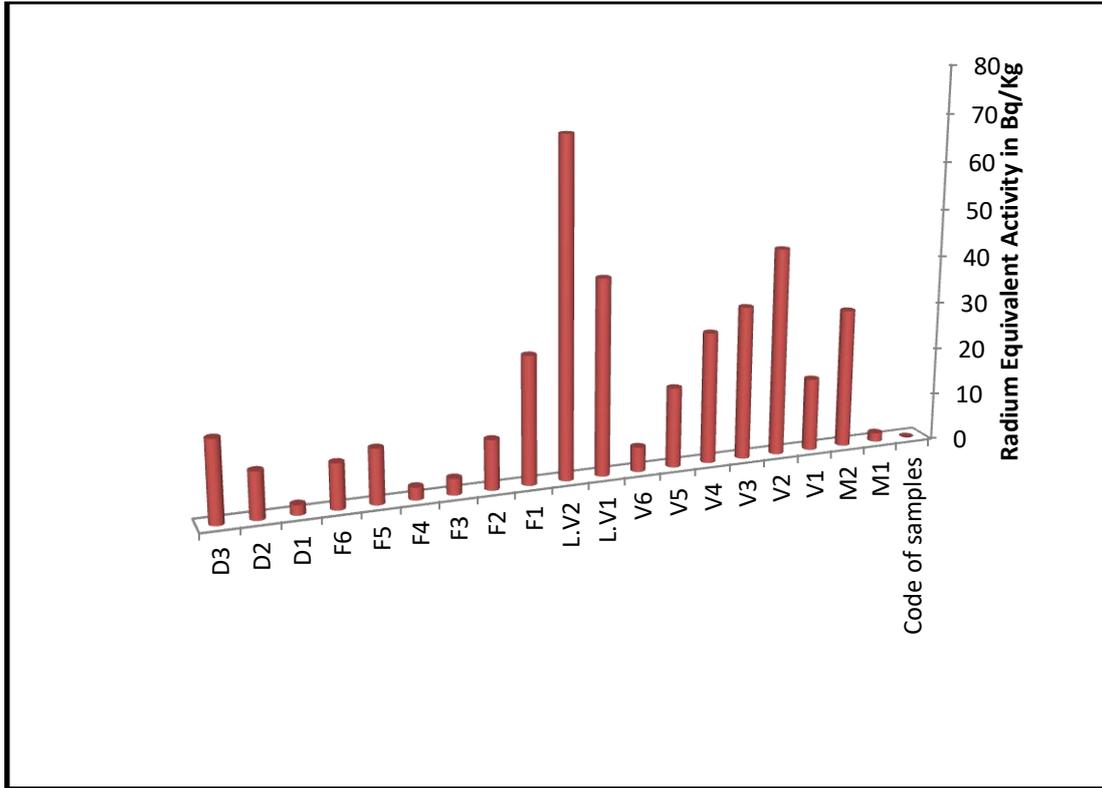
**Figure (4.13): Internal Radiation Hazard in( Bq/Kg) of Food Samples from Hilla City.**

Table (4.11) and Fig. (4.14) show radium equivalent values of food samples from Rumaila area Basra. with an average  $19.921 \pm 28.683$  Bq/Kg, for range  $1.817 \pm 2.804$  Bq/Kg to  $70.417 \pm 101.644$  Bq/Kg ;the radium equivalent values within the allowed limit worldwide median value 370 Bq/Kg ,the average of absorbed dose rate values which are  $9.018 \pm 0.423$  nGy/h with a range  $0.848 \pm 0.201$  nGy/h to  $36.387 \pm 1.191$  nGy/h so the absorbed dose rate within the allowed limit worldwide median value 55 nGy/h as seen in Fig.(4.15), the average of Internal radiation hazard value is  $0.055 \pm 0.003$  Bq/Kg with a range  $0.005 \pm 0.001$  Bq/Kg to  $0.194 \pm 0.010$  Bq/Kg, so all samples within the allowed limit were less than one as shown in Fig.(4.16) .

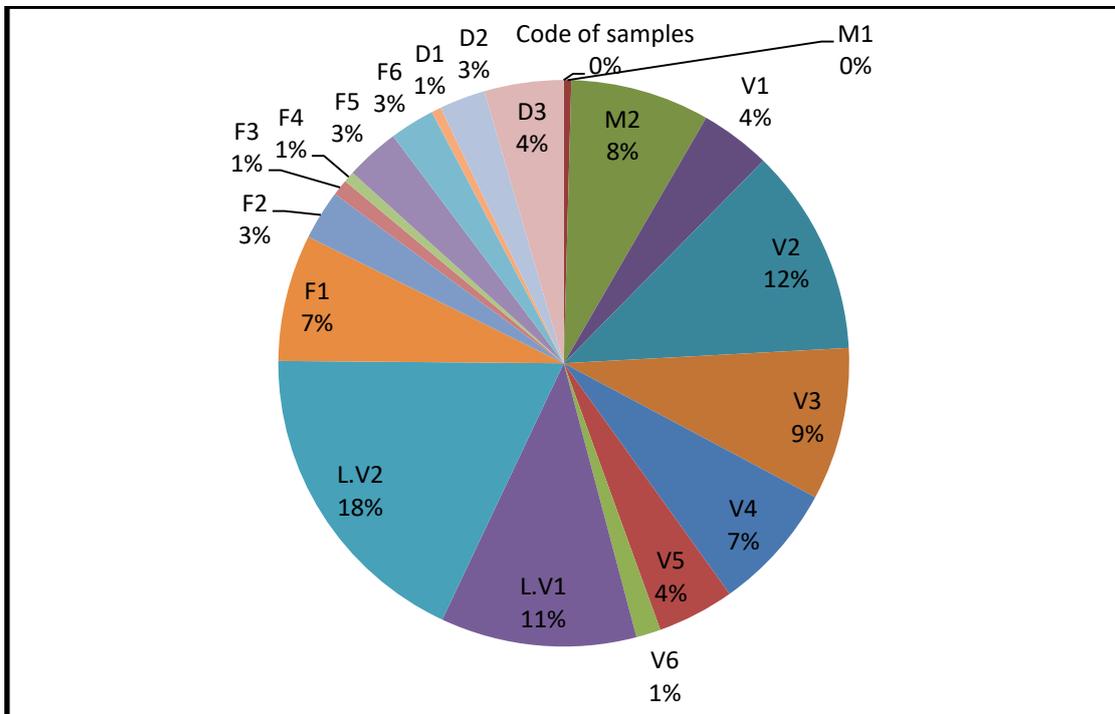
## Chapter Four Results, Discussion and Calculations

**Table (4.11): Radium Equivalent , Absorbed Dose Rate and Internal Radiation Hazard of Food Samples from Rumaila Area, Basra.**

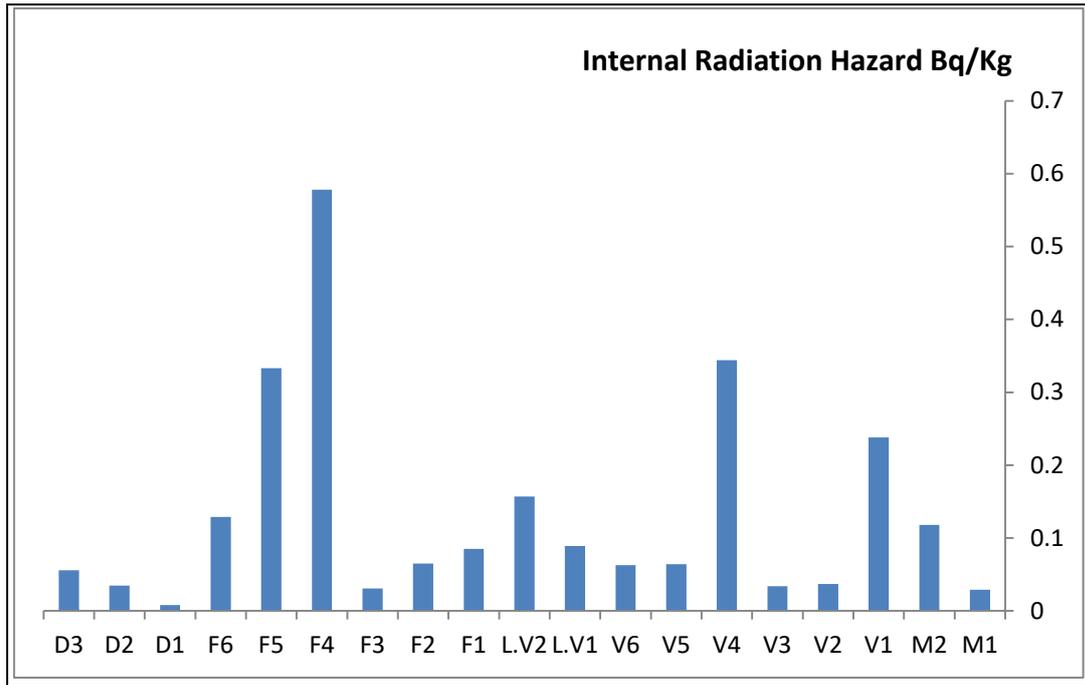
No.	Code of Samples	Radium Equivalent ( $Ra_{eq}$ ) (Bq/kg)	Absorbed Dose Rate (AD) (nGy/h)	Internal Radiation Hazard ( $H_{in}$ ) (Bq/kg)
1	M1	$1.817 \pm 2.804$	$0.848 \pm 0.201$	$0.005 \pm 0.001$
2	M2	$29.457 \pm 42.280$	$15.832 \pm 0.597$	$0.079 \pm 0.002$
3	V1	$15.388 \pm 22.302$	$8.046 \pm 0.619$	$0.045 \pm 0.005$
4	V2	$43.864 \pm 62.806$	$23.709 \pm 0.530$	$0.118 \pm 0.002$
5	V3	$32.355 \pm 46.386$	$17.457 \pm 0.925$	$0.088 \pm 0.005$
6	V4	$27.691 \pm 39.899$	$14.642 \pm 0.886$	$0.080 \pm 0.006$
7	V5	$16.857 \pm 24.426$	$8.774 \pm 0.642$	$0.051 \pm 0.005$
8	V6	$5.197 \pm 7.463$	$2.793 \pm 0.173$	$0.0141 \pm 0.001$
9	L.V1	$41.222 \pm 59.074$	$22.273 \pm 1.244$	$0.111 \pm 0.004$
10	L.V2	$70.417 \pm 101.644$	$36.387 \pm 1.191$	$0.194 \pm 0.010$
11	F1	$26.995 \pm 38.725$	$14.514 \pm 0.425$	$0.073 \pm 0.002$
12	F2	$10.536 \pm 15.112$	$5.681 \pm 0.234$	$0.028 \pm 0.001$
13	F3	$3.479 \pm 5.022$	$1.845 \pm 0.323$	$0.010 \pm 0.001$
14	F4	$2.657 \pm 3.996$	$1.845 \pm 0.323$	$0.009 \pm 0.002$
15	F5	$11.610 \pm 16.734$	$1.257 \pm 0.257$	$0.034 \pm 0.003$
16	F6	$9.595 \pm 13.846$	$6.141 \pm 0.446$	$0.026 \pm 0.002$
17	D1	$2.123 \pm 3.098$	$5.114 \pm 0.322$	$0.007 \pm 0.001$
18	D2	$9.935 \pm 14.339$	$1.092 \pm 0.243$	$0.027 \pm 0.002$
19	D3	$17.314 \pm 25.021$	$5.237 \pm 0.395$	$0.047 \pm 0.002$
Av.		$19.921 \pm 28.683$	$9.018 \pm 0.423$	$0.055 \pm 0.003$
Min.		$1.817 \pm 2.804$	$0.848 \pm 0.201$	$0.005 \pm 0.001$
Max.		$70.417 \pm 101.644$	$36.387 \pm 1.191$	$0.194 \pm 0.010$
World Wide Median Value		$> 370$ [86]	55[87]	$>1$ [86]



**Figure (4.14): Radium Equivalent Activity in (Bq/Kg) of Food Samples from Rumaila Area, Basra.**



**Figure (4.15): Absorbed Dose Rate in (nGy/h) of Food Samples from Rumaila Area, Basra.**



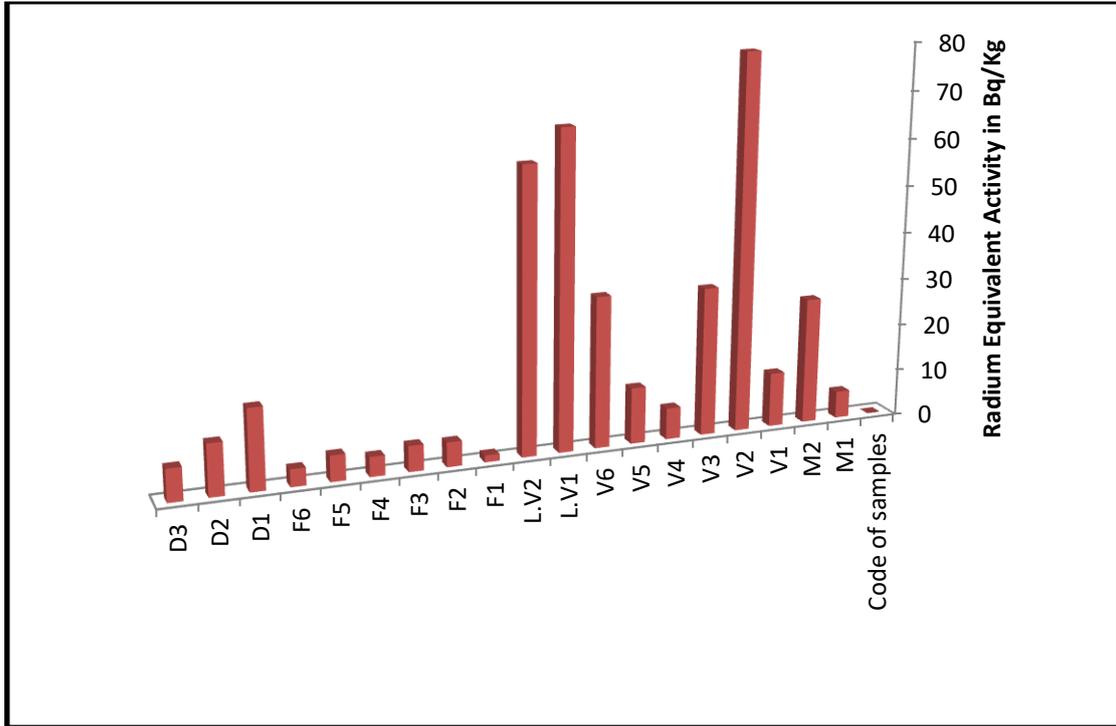
**Figure (4.16): Internal Radiation Hazard in (Bq/Kg) of Food Samples from Rumaila Area, Basra.**

Table (4.12) and Fig.(4.17) show radium equivalent values of food samples from Karbala city. with an average  $20.649 \pm 1.019$  Bq/Kg, for range  $1.459 \pm 0.281$  Bq/Kg to  $79.572 \pm 2.654$  Bq/Kg ; the radium equivalent values within the allowed limit worldwide median value 370 Bq/Kg, the average of absorbed dose rate values which are  $11.051 \pm 0.519$  nGy/h with a range  $0.730 \pm 0.003$  nGy/h to  $42.956 \pm 1.385$  nGy/h so the absorbed dose rate within the allowed limit worldwide median value 55 nGy/h as seen in Fig.(4.18) , the average of Internal radiation hazard value is  $0.057 \pm 0.003$  Bq/Kg with a range  $0.004 \pm 0.001$  Bq/Kg to  $0.216 \pm 0.007$  Bq/Kg ,so all samples within the allowed limit were less than one as shown in Fig.(4.19) .

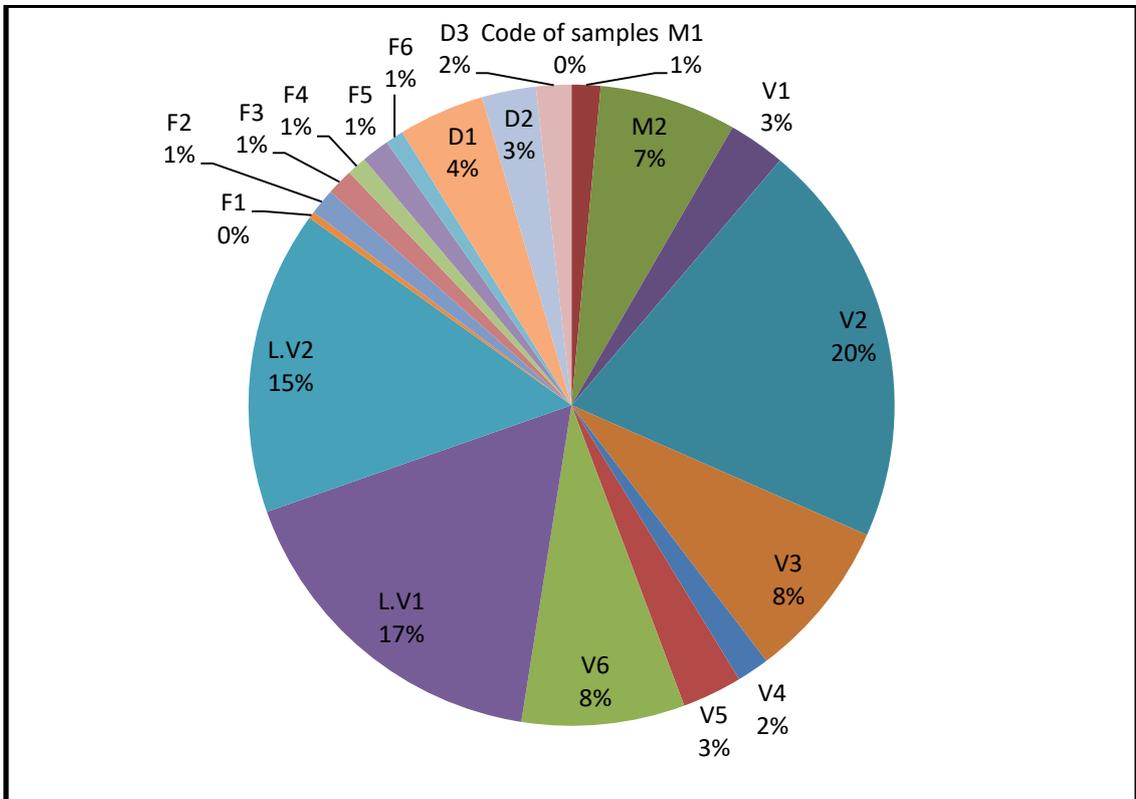
## Chapter Four Results, Discussion and Calculations

**Table (4.12): Radium Equivalent , Absorbed Dose Rate and Internal Radiation Hazard of Food Samples from Karbala City.**

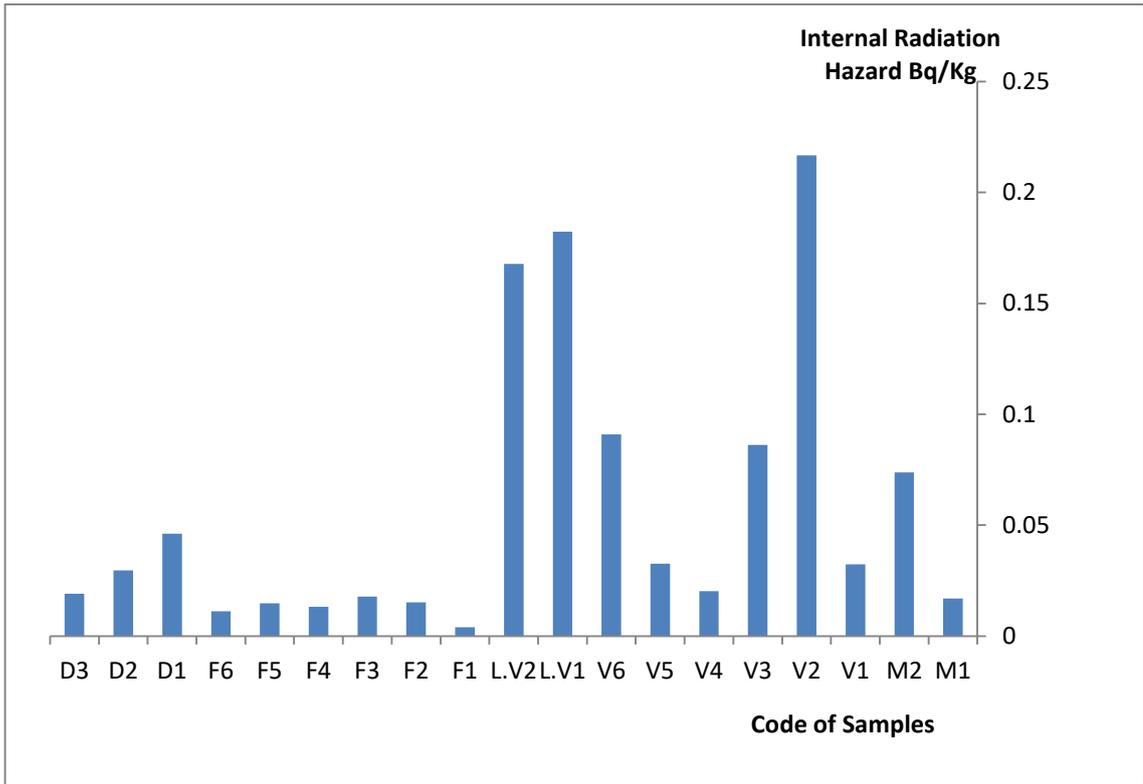
No.	Code of Samples	Radium Equivalent ( $R_{eq}$ ) (Bq/kg)	Absorbed Dose Rate (AD) (nGy/h)	Internal Radiation Hazard ( $H_{in}$ ) (Bq/kg)
1	M1	$5.727 \pm 0.610$	$3.033 \pm 0.307$	$0.016 \pm 0.002$
2	M2	$26.742 \pm 0.974$	$14.418 \pm 0.508$	$0.073 \pm 0.002$
3	V1	$11.461 \pm 1.297$	$6.003 \pm 0.642$	$0.032 \pm 0.004$
4	V2	$79.572 \pm 2.654$	$42.956 \pm 1.385$	$0.216 \pm 0.007$
5	V3	$31.389 \pm 1.437$	$16.935 \pm 0.750$	$0.086 \pm 0.004$
6	V4	$6.618 \pm 0.960$	$3.404 \pm 0.469$	$0.020 \pm 0.003$
7	V5	$11.867 \pm 1.026$	$6.324 \pm 0.518$	$0.032 \pm 0.003$
8	V6	$31.920 \pm 1.057$	$17.134 \pm 0.547$	$0.090 \pm 0.003$
9	L.V1	$66.788 \pm 2.166$	$35.939 \pm 1.117$	$0.182 \pm 0.006$
10	L.V2	$60.058 \pm 2.471$	$32.190 \pm 1.263$	$0.167 \pm 0.007$
11	F1	$1.459 \pm 0.281$	$0.730 \pm 0.003$	$0.004 \pm 0.001$
12	F2	$5.178 \pm 0.488$	$2.755 \pm 0.247$	$0.015 \pm 0.001$
13	F3	$5.439 \pm 0.655$	$2.794 \pm 0.321$	$0.017 \pm 0.002$
14	F4	$4.172 \pm 0.534$	$2.074 \pm 0.256$	$0.013 \pm 0.001$
15	F5	$5.457 \pm 0.454$	$2.923 \pm 0.231$	$0.014 \pm 0.001$
16	F6	$3.682 \pm 0.504$	$1.924 \pm 0.250$	$0.011 \pm 0.001$
17	D1	$17.012 \pm 0.823$	$9.035 \pm 0.414$	$0.046 \pm 0.002$
18	D2	$10.905 \pm 0.627$	$5.696 \pm 0.311$	$0.029 \pm 0.001$
19	D3	$6.889 \pm 0.351$	$3.700 \pm 0.180$	$0.019 \pm 0.001$
Av.		$20.649 \pm 1.019$	$11.051 \pm 0.519$	$0.057 \pm 0.003$
Min.		$1.459 \pm 0.281$	$0.730 \pm 0.003$	$0.004 \pm 0.001$
Max.		$79.572 \pm 2.654$	$42.956 \pm 1.385$	$0.216 \pm 0.007$
World Wide Median Value		$> 370[86]$	$55[87]$	$>1[86]$



**Figure (4.17): Radium Equivalent Activity in (Bq/Kg) of Food Samples from Karbala City.**



**Figure (4.18): Absorbed Dose Rate in (nGy/h) of Foods from Karbala City.**



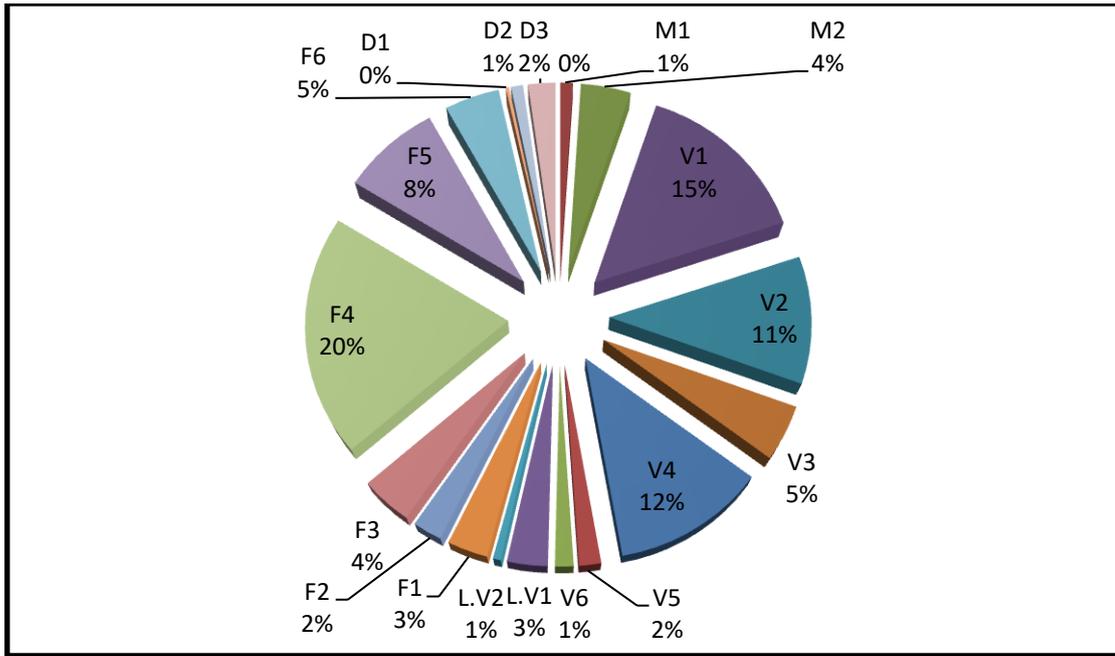
**Figure (4.19): Internal Radiation Hazard in (Bq/Kg) of Foods from Karbala City.**

Table (4.13) and Fig. (4.20) indicate the average of annual effective dose values of food samples from Al-Tuwaitha village, Baghdad which are  $0.144 \pm 0.003 \mu\text{Sv/y}$  with a range  $0.007 \pm 0.001 \mu\text{Sv/y}$  to  $0.566 \pm 0.006 \mu\text{Sv/y}$  ; therefore all samples within the allowed limit (less than one). Fig.(4.21) shows the average of activity concentration index values that are  $0.471 \pm 0.010 \text{ Bq/Kg}$  with a range  $0.025 \pm 0.001$  to  $1.844 \pm 0.022 \text{ Bq/Kg}$  ,the activity concentration index values for (cucumber, sweet pepper, tangerine) are higher than worldwide median value  $1 \text{ Bq/Kg}$  .

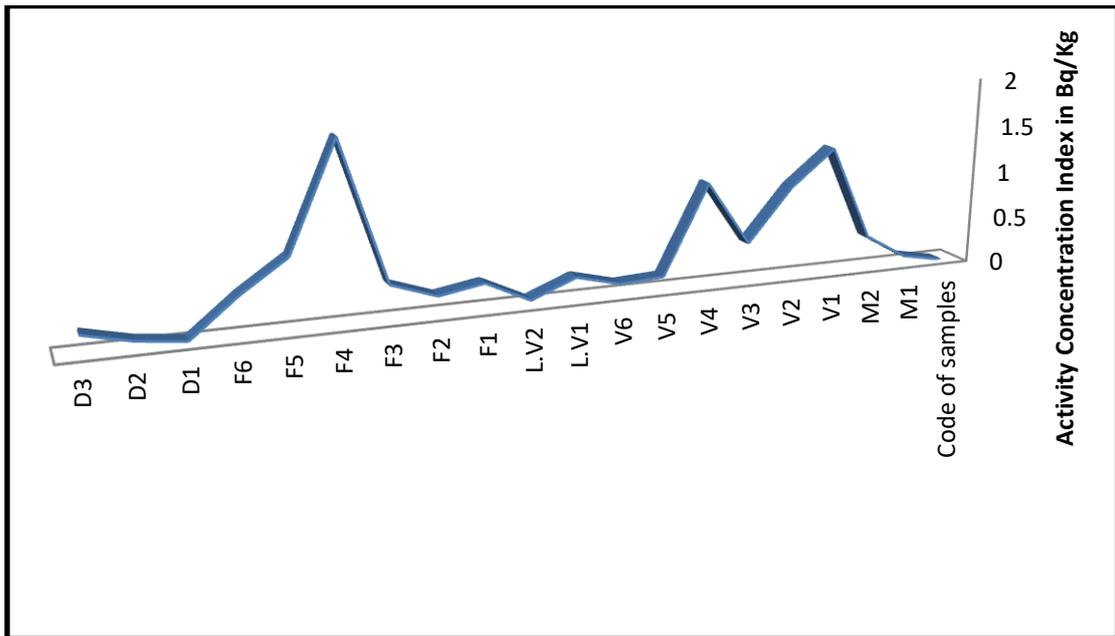
## Chapter Four      Results, Discussion and Calculations

**Table (4.13): The Total Annual Effective Dose and Activity Concentration Index of Food Samples from Al-Tuwaitha Village, Baghdad.**

No.	Code of Samples	Annual Effective Dose (AED) ( $\mu\text{Sv/y}$ )	Activity Concentration Index ( $I_V$ )(Bq/Kg)
1	M1	$0.026 \pm 0.001$	$0.086 \pm 0.004$
2	M2	$0.108 \pm 0.002$	$0.350 \pm 0.007$
3	V1	$0.412 \pm 0.006$	<b><math>1.343 \pm 0.022</math></b>
4	V2	$0.296 \pm 0.004$	$0.967 \pm 0.014$
5	V3	$0.126 \pm 0.006$	$0.412 \pm 0.020$
6	V4	$0.333 \pm 0.006$	<b><math>1.087 \pm 0.021</math></b>
7	V5	$0.045 \pm 0.001$	$0.148 \pm 0.005$
8	V6	$0.037 \pm 0.002$	$0.123 \pm 0.007$
9	L.V1	$0.074 \pm 0.006$	$0.241 \pm 0.020$
10	L.V2	$0.016 \pm 0.001$	$0.053 \pm 0.003$
11	F1	$0.086 \pm 0.002$	$0.280 \pm 0.006$
12	F2	$0.061 \pm 0.003$	$0.201 \pm 0.010$
13	F3	$0.112 \pm 0.003$	$0.365 \pm 0.009$
14	F4	$0.566 \pm 0.005$	<b><math>1.844 \pm 0.018</math></b>
15	F5	$0.226 \pm 0.004$	$0.737 \pm 0.013$
16	F6	$0.126 \pm 0.002$	$0.412 \pm 0.007$
17	D1	$0.007 \pm 0.001$	$0.025 \pm 0.001$
18	D2	$0.026 \pm 0.001$	$0.085 \pm 0.003$
19	D3	$0.061 \pm 0.001$	$0.199 \pm 0.004$
Av.		$0.144 \pm 0.003$	$0.471 \pm 0.010$
Min.		$0.007 \pm 0.001$	$0.025 \pm 0.001$
Max.		$0.566 \pm 0.005$	$1.844 \pm 0.018$
World Wide Median Value		1 [88]	$\geq 1$ [86]



**Figure (4.20): Annual Effective Dose in (µSv/y) of Food Samples from Al-Tuwaitha Village, Baghdad.**



**Figure (4.21): Activity Concentration Index in (Bq/Kg) of Food Samples from Al-Tuwaitha Village, Baghdad.**

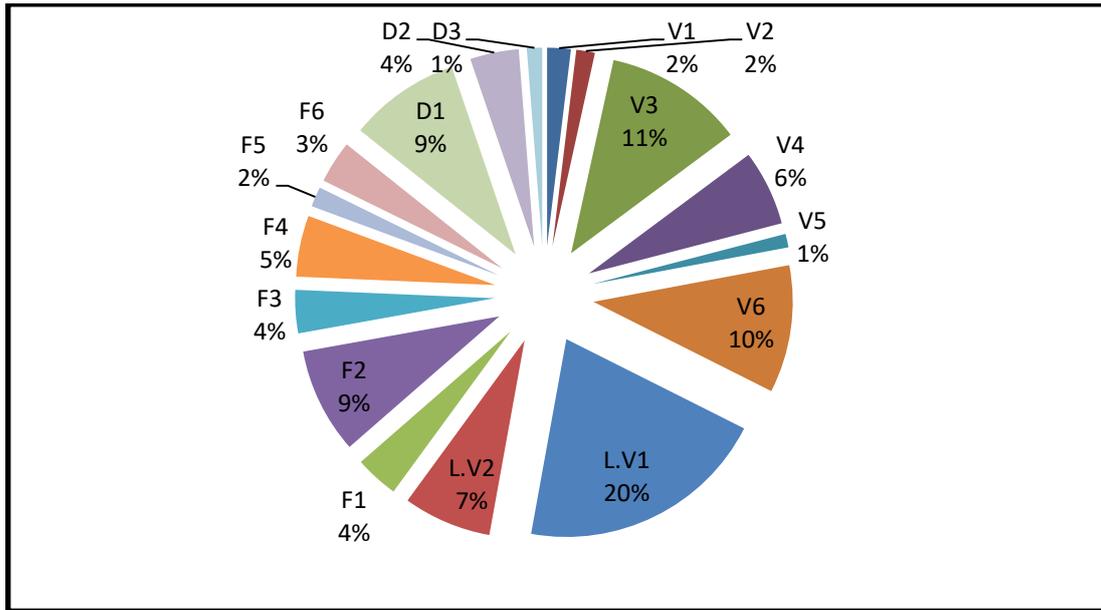
Table (4.14) and Fig. (4.22) indicate the average of annual effective dose values of food samples from Hilla city which  $0.144 \pm 0.003 \mu\text{Sv/y}$  with a range  $0.007 \pm 0.001 \mu\text{Sv/y}$  to  $0.566 \pm 0.006 \mu\text{Sv/y}$ ; therefore all samples within the allowed limit (less than one). Fig. (4.23) shows the average of activity concentration index values that are  $0.471 \pm 0.010 \text{ Bq/Kg}$  with a range

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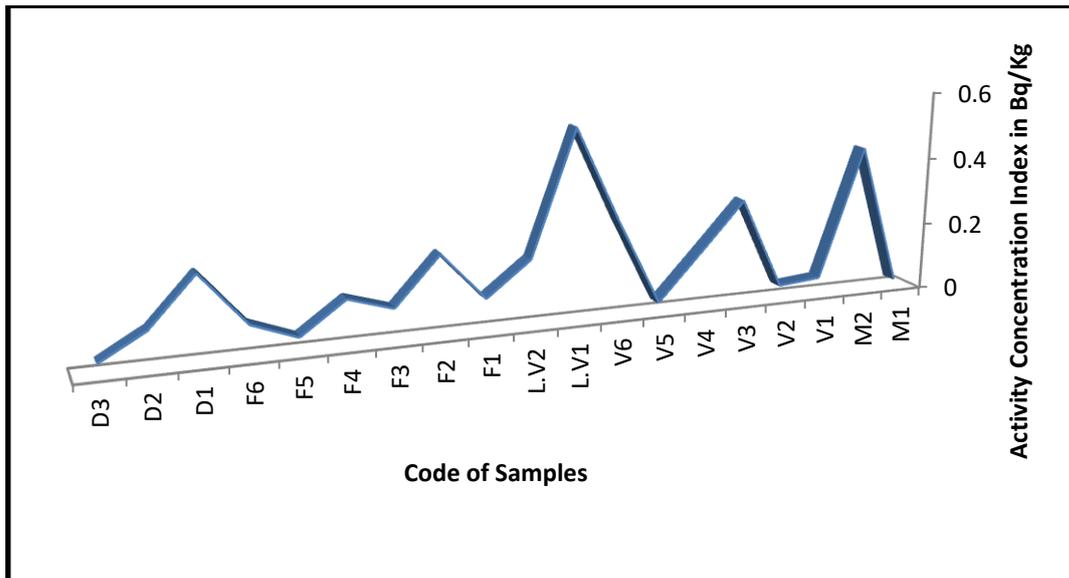
0.025 ± 0.001 to 1.844 ± 0.022 Bq/Kg, the activity concentration index values for (cucumber, sweet pepper, tangerine) are higher than worldwide median value 1 Bq/Kg .

**Table (4.14): The Total Annual Effective Dose and Activity Concentration Index of Food Samples from Hilla City.**

No.	Code of Samples	Annual Effective Dose (AED) (μSv/y)	Activity Concentration Index (I <sub>y</sub> )(Bq/Kg)
1	M1	0.006 ± 0.0003	0.022 ± 0.002
2	M2	0.1342 ± 0.004	0.437 ± 0.012
3	V1	0.016 ± 0.0004	0.052 ± 0.001
4	V2	0.012 ± 0.0004	0.041 ± 0.001
5	V3	0.095 ± 0.005	0.310 ± 0.015
6	V4	0.052 ± 0.002	0.169 ± 0.008
7	V5	0.009 ± 0.0003	0.030 ± 0.001
8	V6	0.088 ± 0.003	0.287± 0.001
9	L.V1	0.172 ± 0.006	0.561 ± 0.019
10	L.V2	0.060 ± 0.003	0.197 ± 0.009
11	F1	0.029 ± 0.001	0.093 ± 0.003
12	F2	0.072 ± 0.002	0.237 ± 0.006
13	F3	0.029 ± 0.001	0.097 ± 0.003
14	F4	0.042 ± 0.001	0.137 ± 0.005
15	F5	0.013 ± 0.001	0.044 ± 0.002
16	F6	0.029 ± 0.001	0.095 ± 0.003
17	D1	0.076 ± 0.003	0.248 ± 0.010
18	D2	0.033 ± 0.001	0.108 ± 0.004
19	D3	0.010 ± 0.001	0.033 ± 0.002
Av.		0.051 ± 0.002	0.169 ± 0.006
Min.		0.006 ± 0.0003	0.022 ± 0.002
Max.		0.172 ± 0.006	0.561 ± 0.019
World Wide Median Value		1 [88]	≥1 [86]



**Figure (4.22): Annual Effective Dose in (µSv/y) of Food Samples from Hilla City.**



**Figure (4.23): Activity Concentration Index in (Bq/Kg) of Food Samples from Hilla City.**

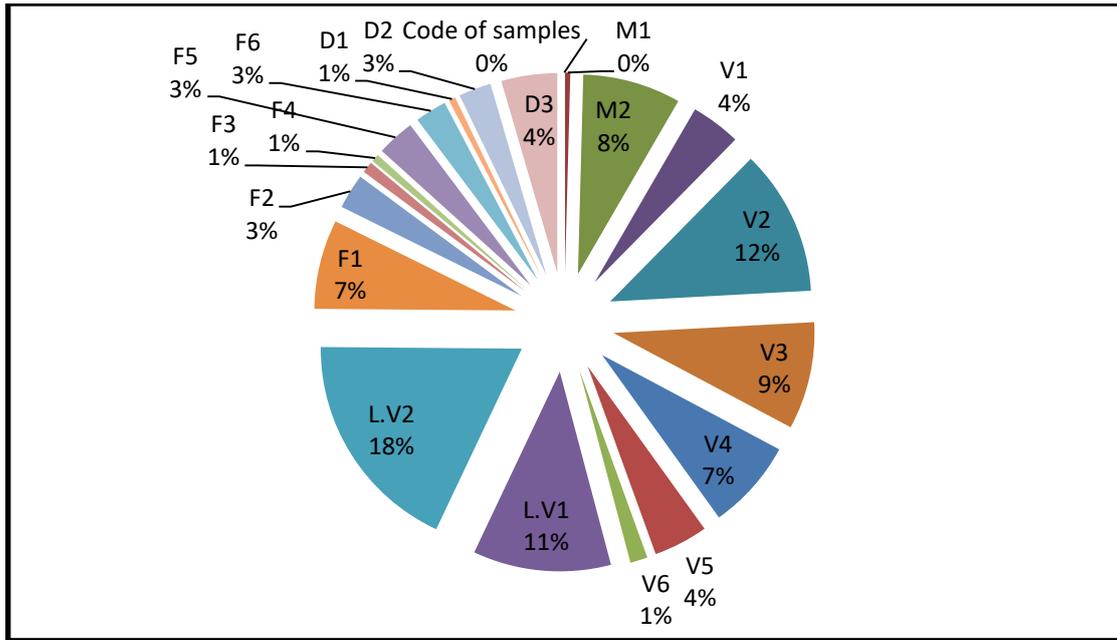
Table (4.15) and Fig. (4.24) indicate the average of annual effective dose values of food samples from Rumaila area, Basra which are  $0.051 \pm 0.002$   $\mu\text{Sv/y}$  with a range  $0.004 \pm 0.001$   $\mu\text{Sv/y}$  to  $0.178 \pm 0.005$   $\mu\text{Sv/y}$ ; therefore all samples within the allowed limit (less than one). Fig.(4.25) shows the average of activity concentration index values that are  $0.168 \pm 0.008$  Bq/Kg with a

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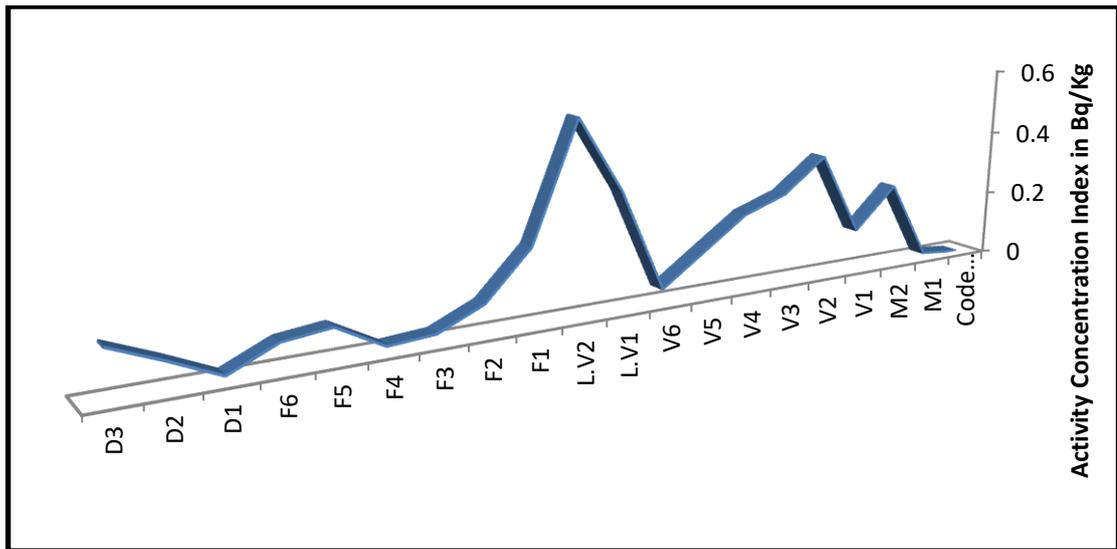
range  $0.013 \pm 0.003$  to  $0.581 \pm 0.026$  Bq/Kg , the activity concentration index values within the allowed limit for worldwide median value 1 Bq/Kg.

**Table (4.15): The Total Annual Effective Dose and Activity Concentration Index of Food Samples from Rumaila Area, Basra.**

No.	Code of Samples	Annual Effective Dose (AED) ( $\mu\text{Sv/y}$ )	Activity Concentration Index ( $I_v$ )(Bq/Kg)
1	M1	$0.004 \pm 0.001$	$0.013 \pm 0.003$
2	M2	$0.077 \pm 0.0029$	$0.253 \pm 0.008$
3	V1	$0.039 \pm 0.003$	$0.127 \pm 0.011$
4	V2	$0.116 \pm 0.002$	$0.378 \pm 0.008$
5	V3	$0.085 \pm 0.004$	$0.278 \pm 0.012$
6	V4	$0.071 \pm 0.004$	$0.232 \pm 0.013$
7	V5	$0.043 \pm 0.004$	$0.138 \pm 0.012$
8	V6	$0.013 \pm 0.001$	$0.044 \pm 0.001$
9	L.V1	$0.109 \pm 0.06$	$0.356 \pm 0.011$
10	L.V2	$0.178 \pm 0.005$	$0.581 \pm 0.026$
11	F1	$0.071 \pm 0.002$	$0.231 \pm 0.007$
12	F2	$0.027 \pm 0.001$	$0.090 \pm 0.003$
13	F3	$0.009 \pm 0.001$	$0.029 \pm 0.003$
14	F4	$0.006 \pm 0.001$	$0.019 \pm 0.004$
15	F5	$0.030 \pm 0.002$	$0.097 \pm 0.006$
16	F6	$0.025 \pm 0.001$	$0.081 \pm 0.005$
17	D1	$0.005 \pm 0.001$	$0.017 \pm 0.003$
18	D2	$0.025 \pm 0.001$	$0.083 \pm 0.004$
19	D3	$0.044 \pm 0.002$	$0.144 \pm 0.007$
Av.		$0.051 \pm 0.002$	$0.168 \pm 0.008$
Min.		$0.004 \pm 0.001$	$0.013 \pm 0.003$
Max.		$0.178 \pm 0.005$	$0.581 \pm 0.026$
World Wide Median Value		1 [88]	$\geq 1$ [87]



**Figure (4.24): Annual Effective Dose in (µSv/y) of Food Samples from Rumaila Area, Basra.**



**Figure (4.25): Activity Concentration Index in (Bq/Kg) of Food Samples from Rumaila Area, Basra.**

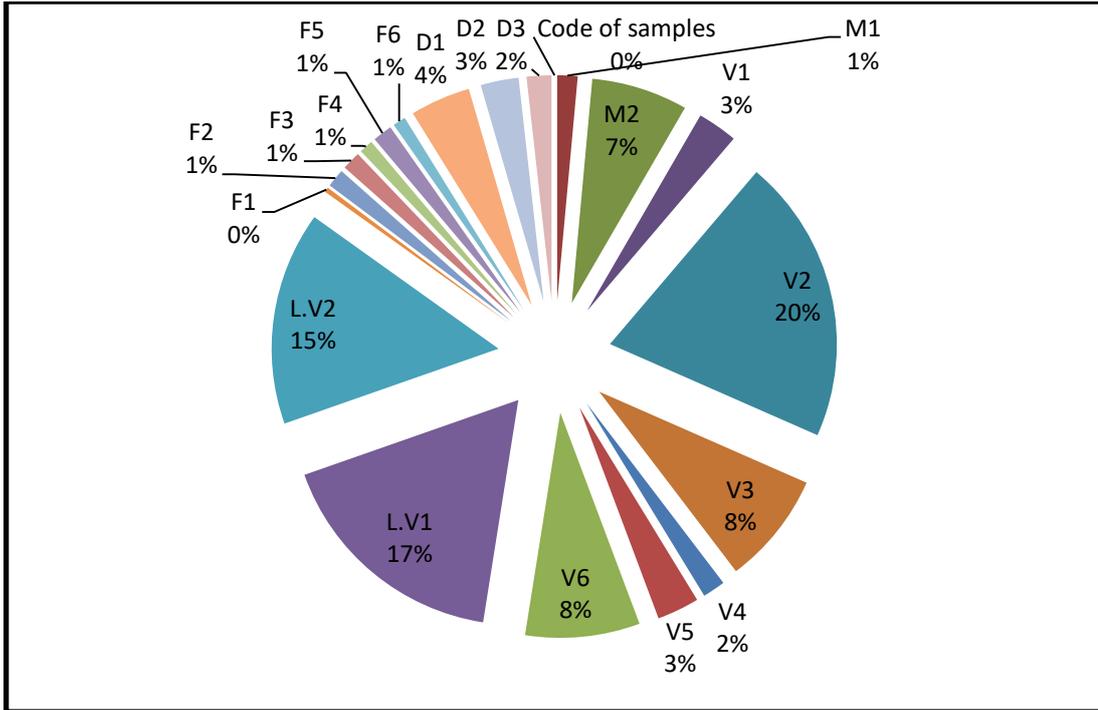
Table (4.16) and Fig. (4.26) indicate the average of annual effective dose values of food samples from Karbala city which are  $0.054 \pm 0.002 \mu\text{Sv/y}$  with a range  $0.003 \pm 0.001 \mu\text{Sv/y}$  to  $0.210 \pm 0.006 \mu\text{Sv/y}$ ; therefore all samples within the allowed limit (less than one). Fig.(4.27) shows the average of activity concentration index values that are  $0.176 \pm 0.008 \text{ Bq/Kg}$  with a range  $0.011 \pm 0.002$  to  $0.686 \pm 0.022 \text{ Bq/Kg}$ , the activity concentration index

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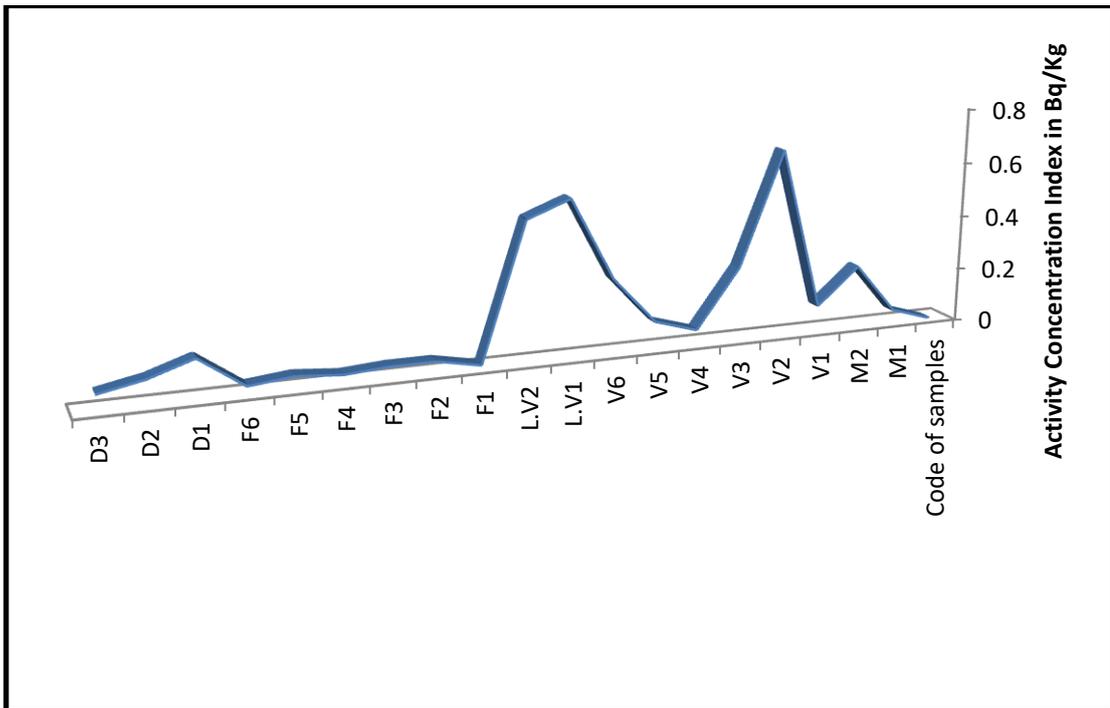
values within the allowed limit for worldwide median value 1 Bq/Kg.

**Table (4.16): The Total Annual Effective Dose and Activity Concentration Index of Foods from Karbala City.**

No.	Code of Samples	Annual Effective Dose (AED) ( $\mu\text{Sv/y}$ )	Activity Concentration Index ( $I_y$ ) (Bq/Kg)
1	M1	$0.014 \pm 0.001$	$0.048 \pm 0.004$
2	M2	$0.070 \pm 0.002$	$0.230 \pm 0.008$
3	V1	$0.029 \pm 0.003$	$0.095 \pm 0.010$
4	V2	$0.210 \pm 0.006$	$0.686 \pm 0.022$
5	V3	$0.083 \pm 0.003$	$0.270 \pm 0.011$
6	V4	$0.016 \pm 0.002$	$0.053 \pm 0.007$
7	V5	$0.031 \pm 0.002$	$0.100 \pm 0.008$
8	V6	$0.084 \pm 0.002$	$0.272 \pm 0.008$
9	L.V1	$0.176 \pm 0.005$	$0.574 \pm 0.017$
10	L.V2	$0.157 \pm 0.006$	$0.513 \pm 0.019$
11	F1	$0.003 \pm 0.001$	$0.011 \pm 0.002$
12	F2	$0.013 \pm 0.001$	$0.043 \pm 0.003$
13	F3	$0.013 \pm 0.001$	$0.043 \pm 0.005$
14	F4	$0.010 \pm 0.001$	$0.032 \pm 0.004$
15	F5	$0.014 \pm 0.001$	$0.046 \pm 0.003$
16	F6	$0.009 \pm 0.001$	$0.030 \pm 0.003$
17	D1	$0.044 \pm 0.002$	$0.144 \pm 0.006$
18	D2	$0.027 \pm 0.001$	$0.091 \pm 0.004$
19	D3	$0.018 \pm 0.001$	$0.059 \pm 0.002$
Av.		$0.054 \pm 0.002$	$0.176 \pm 0.008$
Min.		$0.003 \pm 0.001$	$0.011 \pm 0.002$
Max.		$0.210 \pm 0.006$	$0.686 \pm 0.022$
World Wide Median Value		1 [88]	$\geq 1$ [86]



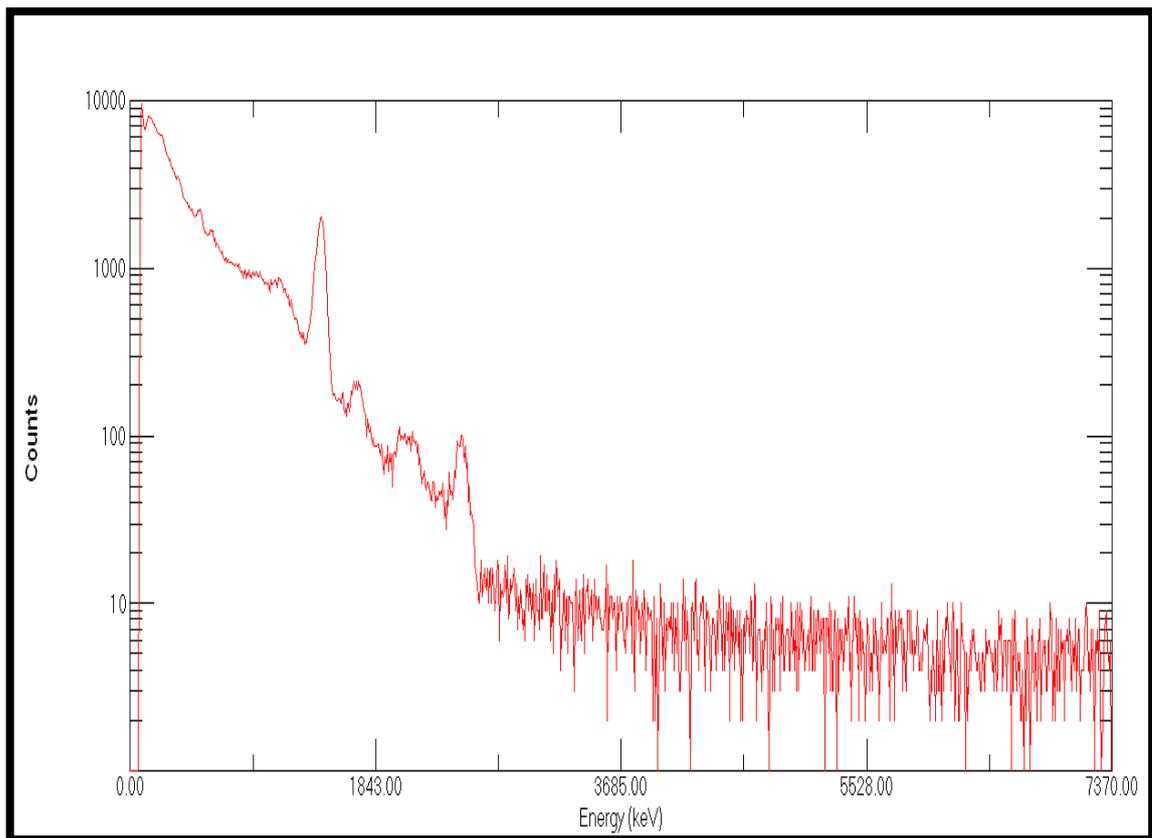
**Figure (4.26): Annual Effective Dose in (µSv/y) of Foods from Karbala City.**



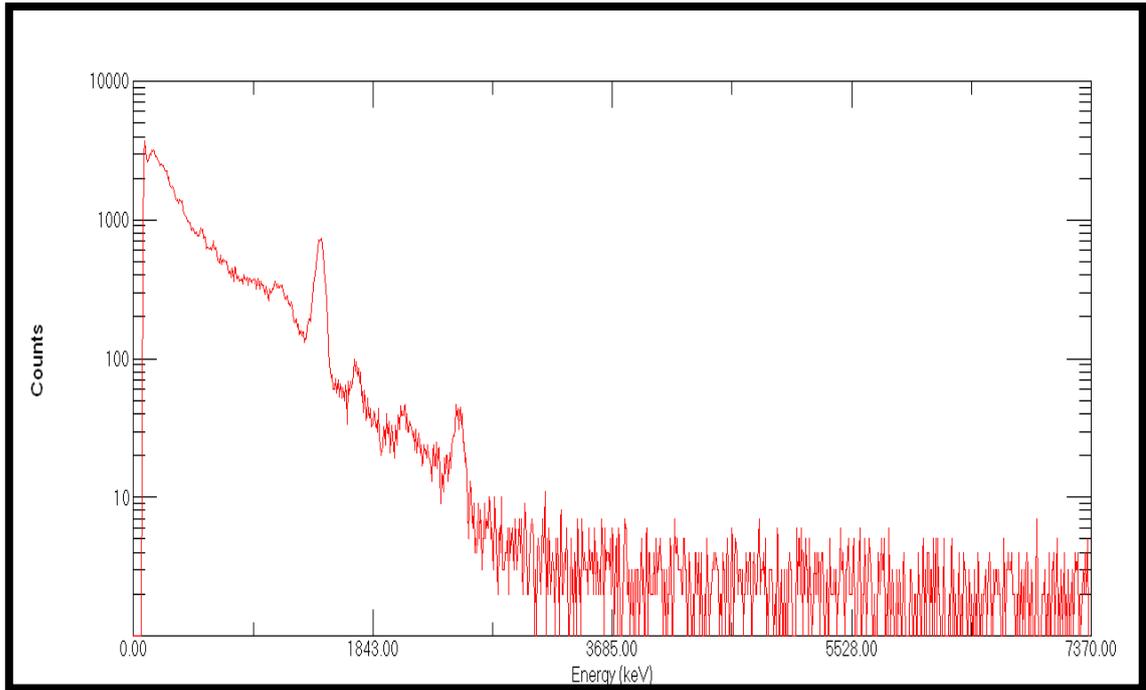
**Figure (4.27): Activity Concentration Index in (Bq/Kg) of Foods from Karbala City.**

**4.5 Samples Spectrum**

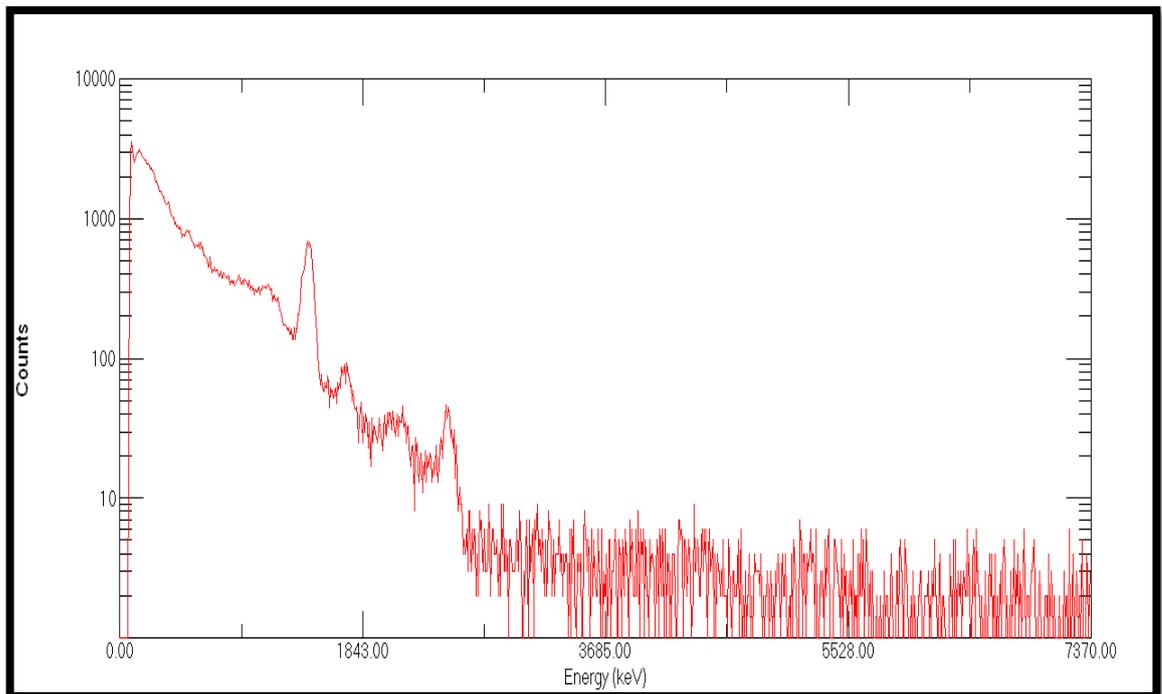
After sampling configured and calibrated detection and measurement system and recording the background spectrum of radiation have been recorded after the gamma-ray spectrum of the samples studied since the measurement time of 18000 seconds , the following Figures: Fig.(4.28), Fig.(4.29), Fig.(4.30) and Fig.(4.31) show some samples of spectra Which were collected from Baghdad, Hilla, Basra and Karbala respectively for the tangerine fruit.



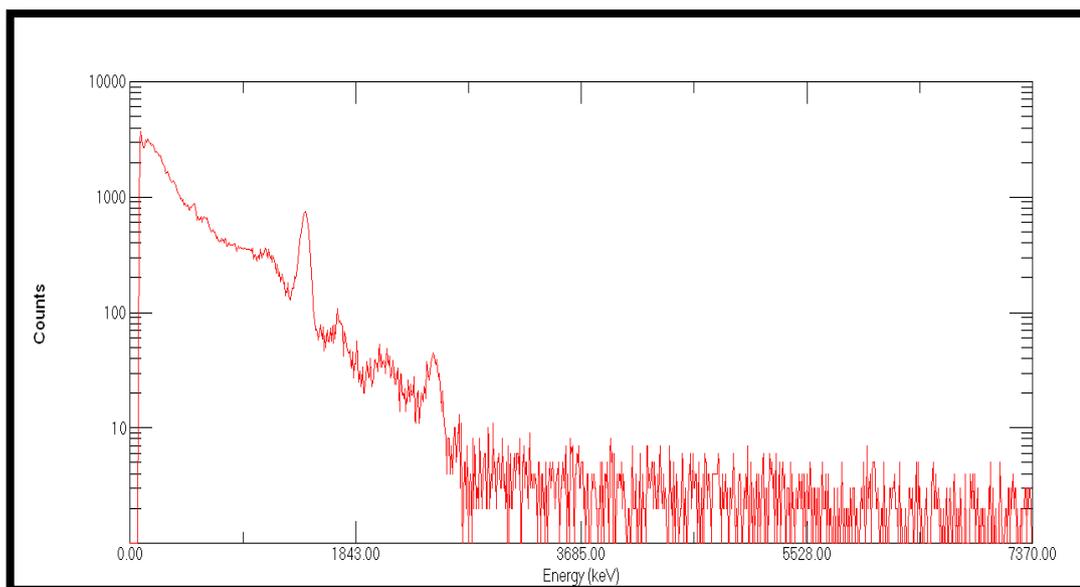
**Figure(4.28): Sample Spectrum F4 from Al-Tuwaitha Village, Baghdad.**



**Figure(4.29): Sample Spectrum F4 from Hilla City.**



**Figure(4.30): Sample Spectrum F4 from Rumaila Area, Basra.**



**Figure(4.31): Sample Spectrum F4 from Karbala City.**

### 4.6 Comparison of the Measured Results

When comparing the current study with other local studies as shown in the Table (4.17), we found :

**Table (4.17):The Comparison between Our Results and the Others.**

Samples	specific activities (Bq/Kg)			city	References
	<sup>238</sup> U	<sup>232</sup> Th	<sup>40</sup> K		
eggplant	6.47±0.37	10.56±0.18	209.56±1.35	Iraq(Kufa)	[28]
okra	BLD	5.06±0.10	138.64±0.86	Iraq (Babel)	
cucumber	BLD	5.06±0.10	226.56±1.34	Iraq (Kufa)	
pepper	BLD	5.76±0.12	147.16	Iraq (Kufa)	
baisl	0.428	1.137	97.237	Iraq (Al-Taji)	[43]
baisl	0.888	1.676	20.636	Iraq(Abu-Ghraib)	[46]
baisl	-	-	983 ± 56	Brazil( Rio de Janeiro)	[38]
oregano	-	-	520 ± 48	Brazil( Rio de Janeiro)	

Where BLD: below level detection

## Chapter Four Results, Discussion and Calculations

### 4.7 statistics

To find the mean radionuclide type and location as shown in Table (4.18) and Fig.(4.32) Statistical program (Genstat) was used ,there are tow factor: radionuclide type factor and city location factor Produces three means

1.City mean: the highest value in Baghdad city is 228.73 Bq/Kg and the lowest value of city mean in Basra city is 76.94 Bq/Kg. Least significant difference( LSD 0.05 Location = 4.45 sig. diff).

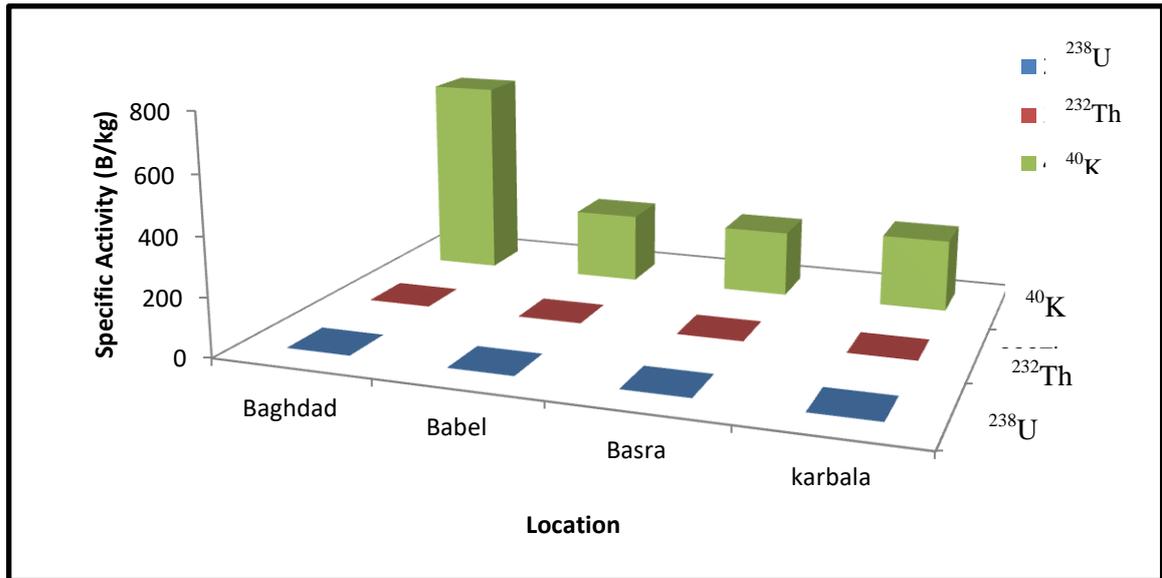
2.Radionuclide mean: the highest value in  $^{40}\text{K}$  is 350. 942 Bq/Kg and the lowest value in  $^{238}\text{U}$  is 0.63Bq/Kg. Least significant difference ( LSD 0.05 Radionuclide type = 3.86 sig. diff).

3.Interaction means between cities and radionuclide: the high value in  $^{40}\text{K}$  is 683.92 Bq/Kg and the lowest value in  $^{238}\text{U}$  and  $^{232}\text{Th}$  is 0.36 Bq/Kg.

There are no significant difference mean with the same litter (between  $^{238}\text{U}$  and  $^{232}\text{Th}$ ) because their values is less than 1. There is a high significant in  $^{40}\text{k}$  .

**Table (4.18): The Mean Radionuclide Type and Location.**

City (Location)	Specific Activity (Bq/Kg)			City Mean (Bq/Kg)	L.S.D of City
	Radionuclide Type				
	$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$		
Baghdad	0.89	1.38	683.92	228.73	4.45
Hilla	0.37	0.37	241.63	80.79	
Basra	0.65	1.14	229.04	76.94	
Karbalaa	0.61	0.55	250.18	83.78	
Radionuclide Mean(Bq/Kg)	0.63	0.86	350. 942	Grand Mean	
L.S.D of Radionuclide Type	3.86				
L.S.D of City and Radionuclide Type	7.71			117.56	



**Figure (4.32) :The Relation between Specific Activity and Location.**

Statistical analysis was carried out based on the statistics of the rate of cancer incidence per 100,000 people for four Iraqi governorates (Baghdad , Hilla , Karbalaa and Basra) as shown in Table (4.19) these data were collected by the the Iraqi Ministry of Health using the Genstat program to find the relationship between the radioactivity rates of radionuclide and the rate of the number of people diagnosed with cancer in some Iraqi governorates, the highest value for cancer cases in 2017 was in Baghdad city, while the lowest value for cancer cases was in 2013 in Karbala city.

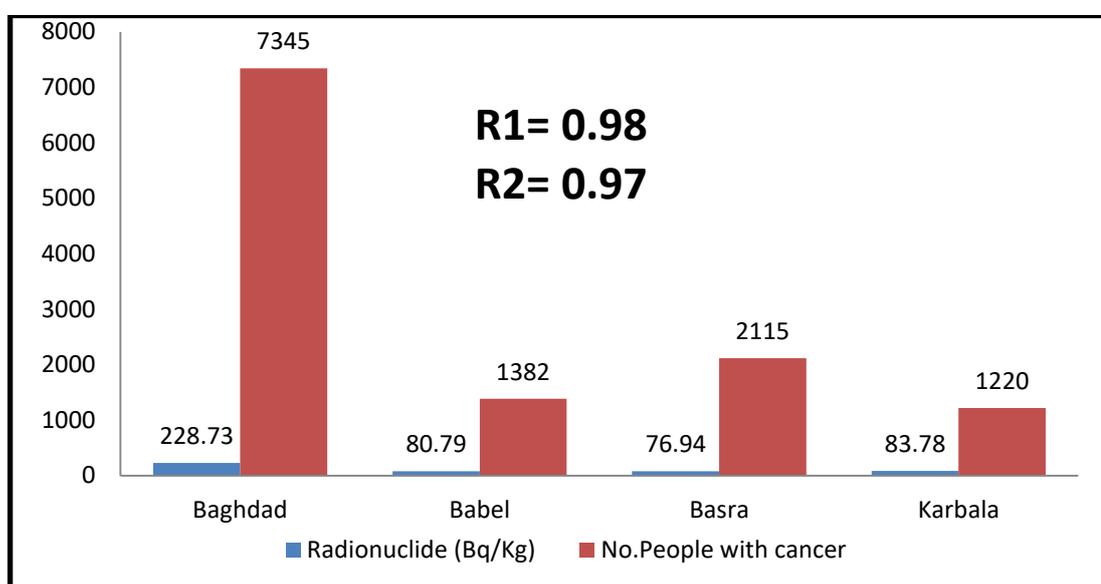
As shown in Fig. (4.33) the highest rate number of people diagnosed with cancer in Baghdad city is 7345, while the least rate number of people diagnosed with cancer in Karbala city is 1220.

The highest rate radioactivity of radionuclide in Baghdad city is 228.73 Bq/Kg, while the least rate radioactivity of radionuclide in Basra city is 76.94 Bq/Kg.

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**Table (4.19 ):Cancer Rates Per 100,000 People for Four Iraqi Governorates.**

City	years					
	2013	2014	2015	2016	2017	2018
Baghdad.	5859	6927	7044	7308	7738	7407
Hilla	1257	1352	1398	1311	1391	1459
Basra	1610	1965	1969	2132	2194	2315
Karbala	993	1089	1166	1328	1327	1191



**Figure (4.33) : The Relationship between the Radioactivity Rates of Radionuclide and the Rate of the Number of People Diagnosed with Cancer in some Iraqi Governorates.**

### 4.8 Conclusions

- 1- Activity concentrations for  $^{40}\text{K}$  high in some samples under study due to clay minerals in the soil which may be attributed to kind of fertilizer used.
- 2- There is slight variation in activity concentrations in some samples of The same type which may be attributed to the environmental conditions.
- 3-The radium equivalents activity ( $R_{\text{aeq}}$ ), absorbed dose rate (AD), activity concentration index ( $I_{\text{v}}$ ) in some samples are higher than the safe limits as recommended by UNSEAR and ICRP due to the entry of foods contaminated

## **Chapter Four Results, Discussion and Calculations**

with radionuclides into the human body at these sites which can pose an internal health risk; therefore it is not safe for people to consume.

4- It can be concluded that eating in the study areas over a long period of time can cause adverse effects.

### **4.9 Future Work**

The natural radioactivity analysis in environmental media's ultimate goal is to provide baseline evidence. The following researches may be done in the future:

1. Studying of the natural radioactivity levels in other regions of Iraq.
2. Studying the natural radioactivity present samples by using HPGe compare the results with the NaI (Tl) detector.
3. Studying ingestion dose of animals from the consumption of and measuring the concentrations of natural radioactivity in the red meats.
4. Studying the natural radioactivity levels for other food crops.

### **4.10 Recommendations**

1. It is necessary to perform more studies and continually for all agricultural areas that contain radioactive waste.
2. It is necessary to use new systems to measure the environmental radioactivity.
3. We recommend reducing the usage of chemical fertilizers as far as possible in the farmland in this region.

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## Summary

Ingestion of radionuclides in foods is considered as one of the reasons of human beings exposure to radiation doses. The sources of radioactivity in the environment have origins which are natural, terrestrial, extraterrestrial and anthropogenic. Radionuclides may be transmitted to plants by deposition or from soil. This study is to evaluate the activity of radionuclides' concentrations ( $^{40}\text{K}$ ,  $^{232}\text{Th}$  and  $^{238}\text{U}$ ) of 76 samples selected from foods (vegetables, leafy vegetables, fruits and meats).

The samples are collected from (Al-Tuwaitha village which lies at the southeast of Baghdad city near the nuclear reactor), Hilla city, Al-Rumaila area which lies at the north of Basra city and Karbalaa city), Gamma rays are measured by using the sodium iodide detector.

The result for Al-Tuwaitha village showed that highest activity value of  $^{238}\text{U}$  in basil is  $3.606 \pm 0.585$  Bq/Kg, of  $^{232}\text{Th}$  in cayenne pepper is  $5.984 \pm 0.710$  Bq/Kg of  $^{40}\text{K}$  in tangerine is  $2757.032 \pm 27.280$  Bq/Kg. The least activity value of  $^{238}\text{U}$  is  $0.038 \pm 0.022$  Bq/Kg, of  $^{232}\text{Th}$  is  $0.063 \pm 0.031$  Bq/Kg and  $^{40}\text{K}$  is  $36.396 \pm 2.171$  Bq/Kg in one kind of dates is called khistawi (in Arabic).

The concentrations of activity of the three nuclides for Hilla city was the highest activity value of  $^{238}\text{U}$  is  $2.796 \pm 0.453$  Bq/Kg in cayenne pepper, of  $^{232}\text{Th}$  in jew's mallow is  $3.226 \pm 0.447$  Bq/Kg and of  $^{40}\text{K}$  in basil is  $825.795 \pm 25.843$  Bq/Kg, the least activity value of  $^{238}\text{U}$  in eggplant is  $0.007 \pm 0.005$  Bq/Kg, of  $^{232}\text{Th}$  in bitter orange is  $0.040 \pm 0.028$  Bq/Kg and of  $^{40}\text{K}$  in fish is  $30.033 \pm 0.0617$  Bq/Kg.

For Al-Rumaila area the highest activity value of  $^{238}\text{U}$  is  $2.031 \pm 0.522$  Bq/Kg in eggplant, of  $^{232}\text{Th}$  in jew's mallow is  $10.502 \pm 0.907$  Bq/Kg and of  $^{40}\text{K}$  in jew's mallow is  $697.279 \pm 21.100$  Bq/Kg, the least activity value of  $^{238}\text{U}$  is  $0.058 \pm 0.030$  Bq/Kg in cowpeas ,of  $^{232}\text{Th}$  is  $0.032 \pm 0.032$  Bq/Kg in orange, and of  $^{40}\text{K}$  is  $6.896 \pm 1.625$  Bq/Kg in fish.

For Karbalaa city the highest activity value of  $^{238}\text{U}$  is  $2.060 \pm 0.364$  Bq/Kg in in jew's mallow,of  $^{232}\text{Th}$  is  $1.316 \pm 0.298$  Bq/Kg in one kinds of dates called zahdi (in Arabic) and of  $^{40}\text{K}$  is  $1014.644 \pm 27.452$  Bq/Kg in okra. The least activity value of  $^{238}\text{U}$  is  $0.039 \pm 0.028$  Bq/Kg in pomegranate, of  $^{232}\text{Th}$  is  $0.094 \pm 0.039$  Bq/Kg in cowpeas and of  $^{40}\text{K}$  is  $11.598 \pm 1.523$  Bq/Kg in pomegranate.

The statistical program Genstat was used to find the relation between the rates of radioactivity of radionuclides and the percentage of the number of people with cancer in the governorate of (Baghdad, Hilla, Basra and Karbala) and the highest percentage was in Baghdad governorate.