University of Kerbala
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Evaluation of the Radiological Risks of Radionuclides in Different Samples of Seasoning in Iraqi Markets

A Thesis

Submitted to the Council of the College of Science, University of Kerbala in Partial Fulfillment of the Requirements for the Master's Degree in Physics Science

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2022 A.D 1444 A.H

بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

﴿ وَيَسْأَلُونَكَ عَنِ الرُّوحِ ۖ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلًا ﴾

صدق الله العلي العظيم

سورة الاسراء

الآية (85)

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Dedication

To Al-Imam AL-Muntazir.

To my Father and my brother Saif (My God have mercy on them).

To my mother who worked so hard for me.

To my husband and children.

To everyone who gave us hope and confidence to reach what we want…

To everyone who encouraged us to continue…

To everyone who repeated to us calls for success…

Alaa

Acknowledgment

Praise to **Allah**, And the Prophet **Muhammad** and his Household and companions and peace. First of all, thanks go for the Almighty **Allah.** The Most Gracious and the most Merciful, for the capability granted to me to complete this research. I would like to express my heartfelt gratitude my deep appreciation to my Supervisor **Prof. Dr. Abdalsattar Kareem Hashim** for suggestion for this project, and to provide assistance, guidance and my advice throughout the work and for many helpful discussions and suggestions. I would like to express my sincere thanks to **Prof. Dr. Ali Abid Abojassim** for To provide assistance, guidance and advice. I would like to express my sincere thanks to head of the Department, **Prof. Dr. Raja Abdul Amir**, the Dean of the College for their support in carrying out this work**. Also,** I would like to thank to the head of Education for Pure Sciences Department (physics Department) **prof. Dr. Ali H.A. Jalaukhan**

. Many thanks to all my colleagues and all members of the nuclear group for their support.

(My thanks and appreciation to my mother, my husband(**Jaafar**), and all generous family for their moral support to help me in this research)

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Alaa

Abstract:

Seasoning (Spice) is one of the main ingredients commonly used In all Iraq Kitchens which is products of tropical plants and maybe bark, roots, buds, fruit, or other parts. It may be contained in the concentrations of some radiation radioactivity nuclides that product from nuclear series, such as uranium-238 series and thorium-232 in addition to the isotope potassium-40. Knowledge of radioactivity levels in human diet is of particular concern for the estimation of possible radiological hazards to human health.

The 57 spices samples collected from several Iraqi markets to measure natural radionuclides. Gamma-ray emitters (^{238}U, ^{232}Th, and ^{40}K) and alpha emitters (^{222}Rn,^{226}Ra, and ^{238}U) measured by gamma-ray spectroscopy and solid-state nuclear track detector, respectively. As well as, radiological risks due to gamma and alpha emitters of samples determined.

The results of gamma emitter show: the average values of the specific activity (S.A) for ^{238}U, ^{232}Th, and ^{40}K,were12.052±1.247Bq/kg,8.760±0.650Bq/kg,and256.924±5.966Bq/kg respectively ,while the global limit according to UNSCEAR for(^{238}U, ^{232}Th, and ^{40}K) are 33 Bq/kg, 45 Bq/kg, and420 Bq/kg ,It is found that all values of $^{238}U$and ^{232}Th the specific activities were less than the worlds average. While all values of specific activity of ^{40}K, that less than worlds average, with the exception of(Coriander origin of Syria) and (Chamomile origin of India) samples were only found to be higher than the worldwide average (420 Bq/kg),Also the result of Radium Equivalent Activity (Ra_{eq}) and Internal hazard index (H_{in}) are 44.315,0.152 respectively , Also, the average values of the total annual effective dose

(AED) due to gamma emitters is 0.0128mSv/y, The average values of threshold consumption rate (DI_{thresh}) is 53.917 kg/y, Also the average of Hereditary Cancer Risk (HCR) is 0.0351×10^{-3} ,the average value of Fatal Cancer Risk(FCR) is 0.0439×10^{-3}, all these value of gamma emitter less than worlds average.

The results of alpha emitter show: the average of concentration of Radon (C_{Rn}) is 0.258 Bq/kg,the average of concentration of Radium (C_{Ra}) is 0.0164 Bq/kg, the average of concentration of uranium (C_U) is 0.264 Bq/kg ,Also The annual average internal dose (Total AAIED) is 0.0300 µSv/y, The average risk of an excess cancer fatality per million person (RECFPMP) is 0.0097 all these value less than worlds average. At last, that natural radioactivity levels (gamma and alpha emitters) together with radiological hazard risk from through comparison with the permissible global limits, as well as comparison with previous local and international studies, it was concluded that the 57 samples of spices that were studied do not cause any danger to the human health when its consumption.

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List of Symbols

Symbol	Description
NORM	Naturally Occurring Radioactive Materials
Bq	Becquerel
Sv	Sievert
^{O}C	Degree centigrade
AED	Annual effective dose
C_{Rn}	Concentration of radon
UNSCEAR	United national scientific committee on the effects of atomic radiation
SSNTD	Soil state nuclear track detector
NaOH	Sodium hydroxide
ICRP	International committee or radiation protection
ATD	Alpha track detector
DTD	Dielectric track detector
P	the track density
HPGe	High Purity Germanium
^{40}K	Potassium-40
^{238}U	Uranium-238
^{232}Th	Thorium-232
^{222}Rn	Radon-222
^{226}Ra	Radium -226
Nal (TI)	Sodium Iodide Thallium Detector
C_U	Uranium Concentration
H_{in}	Internal Hazard Index
RF	Risk Factor
mSv y^{-1}	Milli Sievert per year
N	Normality
FCR	Fatal Cancer Risk
HCR	Hereditary Cancer Risk
AAIED	Annual Average Internal Dose
RECFPMP	Risk of an Excess Cancer Fatality Per Million People
DL	The Life Expectancy
DI_{thresh}	threshold consumption rate

1.1 Introduction

The environment constantly contains naturally occurring radioactive materials, and these sources account for the majority of the public exposure [1]. Depending on their origins, NORM can be divided into two basic groupings. Unlike ^{40}K, which has a half-life of more than 100 million years, terrestrial radionuclides like ^{238}U and ^{232}Th have a natural chain and are not sequenced. Humans are known to be exposed to significant levels of radiation when (NORM) is present in the environment. Radionuclides can be swallowed or inhaled into the body and can originate from either alpha or beta particles. As a result, internal exposure can increase. Gamma radiation, the most common type of exposure to humans, is produced by some of these nuclear types .This suggests that in addition to natural radiation sources, humans are also exposed to radiation from internal and external sources. Inhaling or ingesting radionuclides causes internal radioactive exposure [2]. The dose of inhalation exposure is influenced by the presence of dust particles in the atmosphere, which contain radionuclides from the ^{238}U and ^{232}Th families as well as ^{40}K. The majority of radon exposure through inhalation is caused by short-lived radon breakdown products .In the periodic table, radon is one of the noble gas chains. The radioactive disintegration of the actinium ^{235}U chain, thorium-232, and uranium-238 produces three natural isotopes of radon: actinon (^{219}Rn), thoron (^{220}Rn) , and radon (^{222}Rn). ^{222}Rn is made up of ^{226}Ra decay, which is the direct source of the ^{238}U series, whereas his ^{220}Rn counterpart is made up of ^{224}Ra decay and belongs to the ^{232}Th series [3]. The actinon series is frequently disregarded due to its low air concentration. The natural radioactive chain in the atmosphere, which originates in the Earth's crust, releases radon as a gaseous element. Rocks and soil release radon gas, which is concentrated indoors in places like underground mines and homes [4]. The two sources of radioactive elements found in soil include naturally occurring elements like ^{40}K, ^{232}Th, and ^{235}U as well as man-made elements like ^{137}Cs. The naturally radioactive

elements ^{210}Po and ^{222}Rn are acknowledged as the most notable alpha emitters in terms of internal exposition. Gamma and alpha radiations are mostly dependent on geological and geographical circumstances in the natural world. They can be found at various levels in the soil of different parts of the world. Due to the action of fertilizers on soil, the activity concentration of naturally radioactive elements (radionuclides) in soil and plants is higher in agricultural areas than in uncultivated areas [5]. Radiation effects, on the other hand, can reach soil and water via plants. As a result, tainted plants are devoured by cattle and cows, who are then consumed by humans via the food chain [6]. The majority of humans have a relatively little quantity of uranium in their bodies, mostly in their bones. Despite the fact that uranium is a weakly radioactive element, the majority of the radiation it emits cannot travel far from its source. Most of its radiation can penetrate the epidermis and enter the body if it is outside the body, such as in the soil , most of its radiation can penetrate the skin and enter the body [7]. If uranium transformation products are present, as shown in figure (1-1) one can be exposed to their radiation [8].

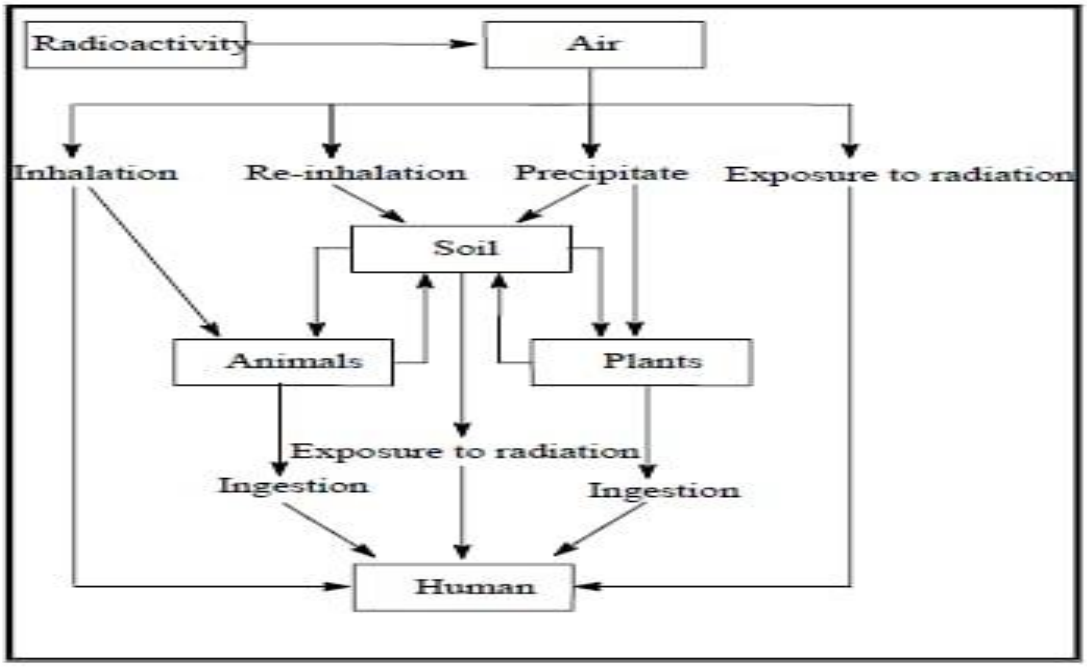

Figure (1-1): Design of Translation of Radiation from Air to the Human Body [8].

Radiation dose from radioactivity concentration (gamma and alpha emitter) of different samples of spice in Iraqi markets, was assessed in this study. Spices was chosen for a variety of reasons: Spice is one of the main ingredients commonly used In all Iraqi Kitchens which is products of tropical plants and maybe bark, roots, buds, fruit, or other parts. It may be contained in the concentrations of some radiation radioactivity nuclides that product from nuclear series, such as uranium-238 series and thorium-232 in addition to the isotope potassium-40. Knowledge of radioactivity levels in human diet is of particular concern for the estimation of possible radiological hazards to human health . As a result, establishing radioisotope concentrations will provide useful information that will aid in the understanding of population exposure and the construction of the original baseline.

1.2 Literature Survey

1.2.1 Studies About Gamma Emitters

No.	Authors	Year	Country	Subject
1	HEF Hemada [9]	2009	Sudan	Using an HPGe detector, the average specific activity of ^{232}Th and ^{40}K in the spice sample were 1.49, 1.63, and 446.41 Bq/kg, respectively..
2	Nada Farhan Kadhim ,and et al , [10]	2012	Iraq	The result show that, the spices do not present any serious hazard and the considered radiologicaly safe for human consumption, using NaI(Tl).
3	Rafat M Amin, and et al,[11]	2013	Egypt	The spices do not pose any significant health hazard and is considered radiological safe for human

				consumption in spice sample, using gamma spectrometry.
4	Ckonsaana , and et al, [12]	2013	Ghana	The result indicate in significant radiological health hazard to the public due to the consumption of spices via foods, using NaI(Tl).
5	Lord ford tettey-larby, and et al, [13]	2013	Ghana	The radiological hazard associated with intake of the natural radionuclide in the medical plants is insignificant ,using NaI(Tl).
6	CP Ononugbo , and et al, [14]	2017	Nigeria	The result indicate insignificant radiological health hazard to the public due to the consumption of spices via foods ,using gamma spectrometry .
6	AH Al-Mashhadni, and et al, [15]	2020	Iraq	The value is low compared to the average radiation dose of 290 μSvy-1 received per caput worldwide due to ingestion the food spices ,using gamma spectrometry .
7	P Nochit, and et al, [16]	2021	Thailand	The result provide base line values which may be useful in establishing rules and regulations relating to radiation protection ,using gamma spectrometry .

1.2.2 Studies About Alpha Emitters

No.	Authors	Year	Country	Subject
1	Nidhala H K Al-Ani, and et.al.[17]	2010	Iraq	The results show that the maximum Concentration for spices samples recorded is equal to (6.9621 ± 0.111) ppm .The minimum concentrations were (1.5360±0.084) ppm. using nuclear track detectors of type (CR–39) .
2	L Oufni, and et al,[18]	2013	America	According to the findings, ^{222}Rn and ^{220}Rn transfer factors (TF) from soil to several investigated plants sections have been identified. (TF) was higher for roots than for stems and leaves. Researchers have discovered that the radon and thoron activity in soils range from 0.870.06 Bq/kg to 6.20 0.47 Bq/kg and, accordingly, from 30 ±2.30 mBq/kg to 195 mBq/kg. These values are lower in the leaves and stems of the medical plants under study than they are in the roots, as assessed by nuclear track detectors of type (CR-39).
3	Ali Abid Abojassim, and et al,[19]	2016	Iraq	The finding indicate that the radon concentration average 26.5373.21 Bq/kg these radon concentration value were lower than those reported in literature. using nuclear track detectors of type (CR–39) .
4	Ononugbo,	2018	Nigeria	The activity concentration of ^{222}Rn in

	and et al,[20]			natural food spices range from 0.57 to 686.19 Bq/m^3.The mean annual effective dose from ingestion of ^{222}Rn and inhalation from the food spices are 15.39and 0.72 μSvy^{-1} respectively , using nuclear track detectors of type (CR–39) .
5	H N Alkafaji, and et al,[21].	2019	Iraq	The result have revealed that the radium and uranium concentration as well as exhalation rate in studied medical plants and the associated exhalation radon goes not pose to human health . using nuclear track detectors of type (CR–39) .
6	Malik, and et al,[22]	2020	Iraq	In this work the radon concentrations in the samples were found to vary from 65.102 to 195.30 Bq/m^3 with 126.47 Bq/m^3 a mean value, this mean value is a small amount over 100 Bq/m^3 the reference level limits of the World Health Organization (WHO), below 200 Bq/m^3 of the UK Board of National Radiation Protection (NRPB) limits and below the level of the European Recommendation Commission.

7	Safa, and et al,[23]	2021	Iraq	The concentrations of radon and uranium in the selected samples were measured by recording the fission effects in the CR-39. The concentrations were determined by the calculations based on comparison with the standard samples. In the results obtained, the uranium concentrations in the samples are among the internationally permitted values according to the international organization Atomic Energy Agency IAEA.

1.3 Aim of the Present Study

The aim of this work is to evaluate gamma and alpha emitters in different Samples of Spices(seasoning) in Iraqi Markets . These goals could meet with completing the following sub-objectives:

1. The specific activity levels of ^{238}U, ^{232}Th, and ^{40}K (gamma emitters) in spices samples are being measured using NaI(Tl) detector.
2. Determining radon concentrations and calculating effective radium contact as well as uranium concentrations (alpha emitters) in same spices samples using CR-39 detector developed by TASL company.
3. Determining Annual effective dose(AED), Fatal Cancer Risk(FCR),and Hereditary Cancer Risk(HCR), as well as The threshold consumption rate(, DI_{thresh}) due to gamma emitters, and also health impacts The annual average internal dose(AAIED)and the risk of an excess cancer fatality per million

person (RECFPMP) due to alpha emitter in all samples on the present study are being calculated.

4. Comparing the results with global limits in addition to comparing them with previous local and international studies.

2.1 Introduction

The term "radioactivity" is used to describe the pace at which elements disintegrate over time. For any element to stay stable, it must have a specific number of neutrons to proton ratios; as a result, any variation from this value will result in an unstable atom. An unstable atom can become stable by creating energy in the form of radiation. The process is known as radioactivity , and such atoms are considered to be radioactive [24].

2.2 Radiation

Radiation is a physics term that refers to the movement of energetic particles or waves through a material or space. Ionizing and non-ionizing radiation are the two types of radiation that are often detected in the way they interact with normal chemical matter, depending on the radiation energy [24]. Radiation comes from a variety of sources, including atomic energy, nuclear power, and radioactivity [25]. Radiation is all around us at all times and in all places. Ionizing radiation has been exposed to all forms of life on Earth, and it has become an inextricable element of our lives. Natural and human-made radionuclides both emit background radiation. Radiation from outer space causes radionuclides to naturally enter the atmosphere. Radionuclides in food and water as well as in the earth's crust's rocks, mineral ores, and soil affect our bodies [26].

2.3 Types of Radiation

Many different types of nuclear radiation are released during various radiation processes, each with its own characteristics such as mass, charge ,and the ability to penetrate mediums and materials [27].

2.3.1 Alpha Particles

An alpha particle is a positively charged particle emitted in the radioactive decay of some unstable atoms. It consists of two protons and two neutrons (it is essentially the nucleus of a helium atom) and thus its heavier and slower-moving than other decay emissions. The decay process of alpha particles is[28]:

$$^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}He(\alpha) \qquad (2.1)$$

where X and Y are initial nuclide (parent) and final nuclide (daughter), respectively, A is the mass number, Z is the atomic number.

Alpha particles do not penetrate deep into a material and can be stopped quite easily (e.g. by a thin piece of paper or skin). However, they are capable of breaking chemical bonds (which can cause chemical or biological damage) when they strike a molecule because of their size, mass, and charge. (Penetration distance of alpha particles depends upon the energy with which they are emitted and the material through which they are passing) [28]. Thus, alpha emitters (such as Uranium-238, Radium-226, and Radon-222) are mostly damaging if they are ingested or inhaled into the lungs [29].

2.3.2 Beta Particles

A beta particle is emitted during the radioactive decay of some unstable atoms. Beta particles can have either a negative charge (electron) or a positive charge (positron). In addition, they have the same very small mass (1/2000 the mass of a neutron) regardless of charge. The beta decay process can occur in three possible ways [30]:

$$\beta^- \, decay: n \rightarrow p + \beta^- + \nu^- \qquad (2.2)$$

$$\beta^+ \, decay: p \rightarrow n + \beta^+ + \nu \qquad (2.3)$$

$$EC \, decay: p + e^- \rightarrow n + \nu \qquad (2.4)$$

Beta particles can penetrate deeper than alpha particles (Its penetration distance depends upon the energy of beta particle and material used). However, they can be stopped fairly easily by a sheet of aluminum [31].

2.3.3 Gamma radiation

Gamma radiation have no electric charge, so they cannot be deflected by electric and magnetic fields [32]. Also gamma rays are an electromagnetic wave. The gamma radiation wavelength is short, with corresponding energies ranging from approximately 0.1 to 10 MeV. Gamma radiation originates as a result of the energy changes are associated with the re-arrangement of the particles in the

nucleus after the release of an alpha or beta particle. The nucleus produced, after this emission, can be in a high energy or excited state and release this excess of energy and return to the ground state; it released this energy as a photon of gamma radiation. Thus, gamma rays are a kind of nuclear spectrum, connected to the level of nuclear energy without any change in the mass of the nucleus atomic number [33]. Gamma ray can be interacted with matter by three main process: Photoelectric phenomenon, Compton scattering and Pair production.

Concerning photoelectric phenomenon, all the energy of an incident photon (gamma rays) is completely absorbed by an electron bound in the inner orbitals of the atom and then leaving it as a positive ion (see Figure (2.1)). The photoelectron shows up with the energy provided by [33]:

$$E_e = h\nu - E_b \qquad (2.5)$$

where E_e represents the kinetic energy of the photoelectron, $h\nu$ is the energy of the incident gamma rays and E_b is the binding energy of the original shell of the photoelectron.

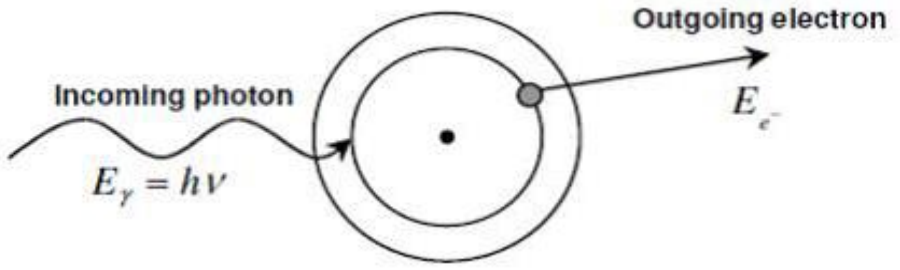

Figure (2.1) Schematic diagram of Photoelectric Effect [33**]**

Concerning Compton scattering is inelastic collision between a photon and a free electron, an incident photon (energy E_γ) interacts with an atomic electron which causes the electron to be no exited from atom (see Figure (2.2)). The incident photon, however, only transfers part of its energy to the ejected electron and the rest is carried away by a secondary scattered photon (energy $E_{\gamma-}$). The energy of the scattered photon is given by [34].

$$E_{\gamma^-} = \frac{E_\gamma}{1 + (\frac{E_\gamma}{m_o c^2})(1 - cos\theta)} \qquad (2.6)$$

where m_o represents the rest mass of electron, c is the speed of light and θ is the angle of scattering.

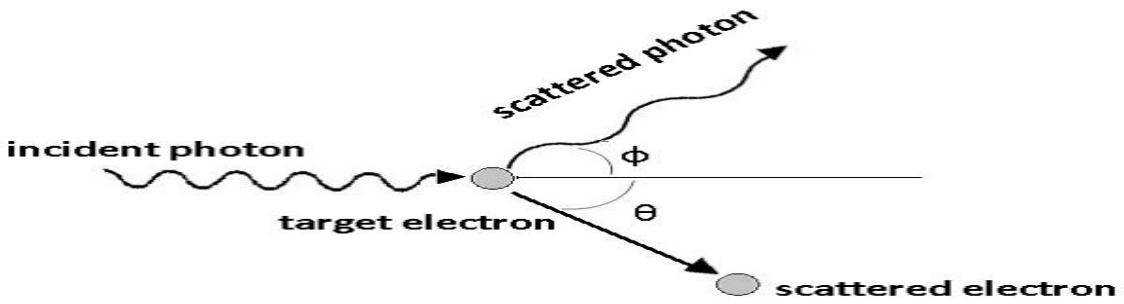

Figure (2.2) Schematic diagram of Compton scattering [34].

Concerning pair production can occur in the presence of or next to a third body, which is the nucleus. Once created, that electron-positron pair, and also for the process of pair production to occur it must be $h\nu \geq 1.022$ MeV [35]. The energy of the photon can be determined by using the following equation [35]:

$$E_\gamma = T^+ + m_o c^2 + T^- + m_o c^2 \qquad (2.7)$$

where T^+ and T^- are positron and electron kinetic energies.

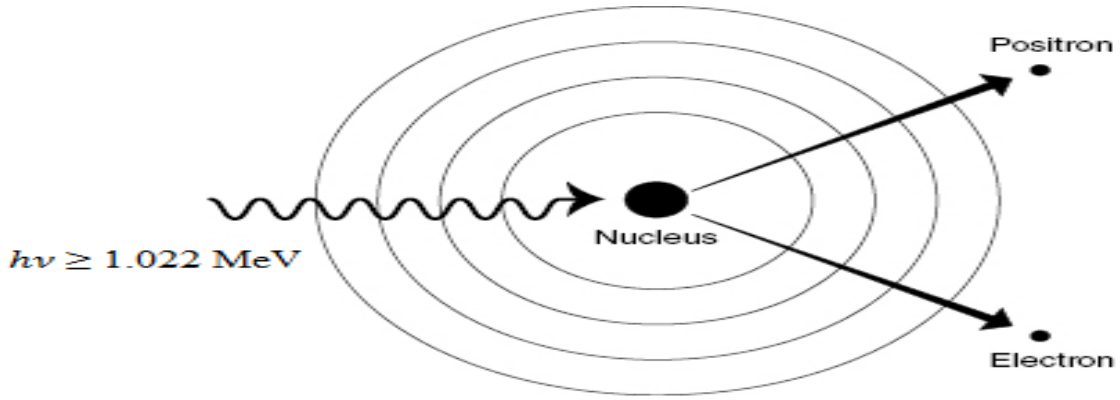

Figure (2.3) Schematic diagram of Pair production mechanism [35].

2.4 Radiation sources

The following are two sources of radioactivity (background radiation):

2.4.1 Natural Radiation

Natural radioactivity is influenced by both extraterrestrial sources and radioactive components in the earth's crust [36]. Natural radiation is the largest contribution to the total dosage received by the world's population, hence assessing it is crucial. Natural sources of radiation are classified in to [[37]:

2.4.1.1 Cosmic Radiation

High-energy particles from outer space bombard the earth on a regular basis. These cosmic rays interact with the nuclei of the elements that make up the atmosphere, setting off a chain reaction that produces a series of interactions and reaction byproducts that cause cosmic ray exposures to decrease in intensity as they penetrate further into the atmosphere. Additional radionuclides another class of radioactive nuclei, also produced by cosmic-ray interactions. ^{3}H and ^{14}C [38] are the best examples. At the ground level, the cosmic-ray field is dominated by a parent with energies between 1 and 20 GeV, which is responsible for around 80% of the absorbed dose rate from directly ionizing radiation in free air [39].

2.4.1.2 Terrestrial Radiation

Radionuclides' terrestrial is lived very long species which have been present on form the earth before about four billion years. They are divided to two types: first is the series of radionuclide which are beginning by radionuclides that are the parents of radionuclides that decay in a series of other nuclear radiation isotopes with varying half-lives and modes of disintegration, eventually decaying to stable isotopes [40]. Terrestrial radiation radionuclides are mainly derived from three separate decay chains, Thorium–232, Uranium–238 and Uranium–235 , as noted in Figure (2.4) [41]. Second is non-series radioactive elements decay into stable nuclides in a direct process. The isotopes of potassium-40 are the most significant radionuclides in this group which it is the most significant

radionuclide for the population . Figure (2.5) is shown the gamma spectrometry of ^{40}K isotope [42].

2.4.2 Man-made Radiation

Man - made radiation sources included X-ray devices, particle accelerators and nuclear reactors used in nuclear power generation, testing and the development of radionuclides which are then used in medicine, science and industrial operations. Past testing of nuclear apparatuses in the atmosphere also leads to global exposure. Occupational exposure, i.e, the exposure of workers is widespread, but involves groups of limited size [37].

2.5 Uranium Decay Series

This series starts with ^{238}U nuclei (half-life 4.49×10^9 years) and progresses through alpha and beta particle emission sequences until ^{206}Pb, a stable nucleus. This chain still exists today because nuclides have such a long half-life. figure(2-4) displays the members of this series in order of mass number in the (4n+2) system [40,42]. This decay series includes ^{226}Ra, a radioactive isotope with a half-life of 1600 years and chemical characteristics distinct from Uranium. ^{222}Rn is formed when ^{226}Ra decays .It can easily be detached from ^{226}Ra and its other long-lived progenitors, becoming a subseries, or it can migrate away from them. The primary one has a half-life of (3.825) days and is radon-222. ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po are transition products with half-lives that range from (26.8) minutes to (160) μs. Lead-210, a durable radon transition product, is the leading member of the final subseries of ^{238}U. The atmosphere contains significant concentrations of lead-210 as well as its derivatives ^{210}Bi and ^{210}Po. The stable end result of this subseries, as well as the conclusion of the ^{238}U series, is ^{206}Pb [41,42].

2.6 Actinium ^{235}U Series

It is also known as Uranium-235 series and starts with ^{235}U and by successive transformations ends up in a stable lead ^{207}Pb. Since its abundance is

very small, it has not taken into account in our measurements. The elements of this series which are represented in a figure (2.4) are arranged according to the mass number indicated in (4n +3) system [40,41].

2.7Thorium Decay Series

The thorium series is further broken down into the ^{232}Th, ^{228}Ra, and ^{220}Rn subseries. In general, radioactive equilibrium exists between the subseries ^{228}Ra, ^{228}Ac, ^{228}Th, and ^{224}Ra. Thorium emanation, or ^{220}Rn, is the dominant component of the third subseries. It has a half-life of (54.5) seconds and quickly decays into stable ^{208}Pb, the longest of which is (10.6) hours ^{212}Pb. Due to the short half-life of ^{220}Rn and the subsequent production of ^{208}Ti, substantial radiation exposures from thorium recovery leftovers can be caused by (2.62) MeV gamma rays. According to the provided mass number, the members of this series, as shown in Figure (2.4), are organized in the (4n) system [40,41].

2.8 Potassium ^{40}K radionuclide

Natural Potassium contains (0.0117%) ^{40}K, which decays with a half-life ($1.28\times l0^{9}$) years see in figure (2-5) the decay scheme sketched below [40]. Potassium-40 contributes (40%) of the exposure humans receive, from natural radiation. It undergoes radioactive transformation both by electron capture (10.32 %) and beta particle emission (89.28 %). The beta particle has a maximum energy of (1.46 MeV). Electron capture is followed by emission of a (1461) Kev gamma ray in (10.7%) of the transformations of ^{40}K, conversion electrons (0.3%) of ^{40}K transformations, and the usual low-energy Auger electrons and characteristic X-rays [42].

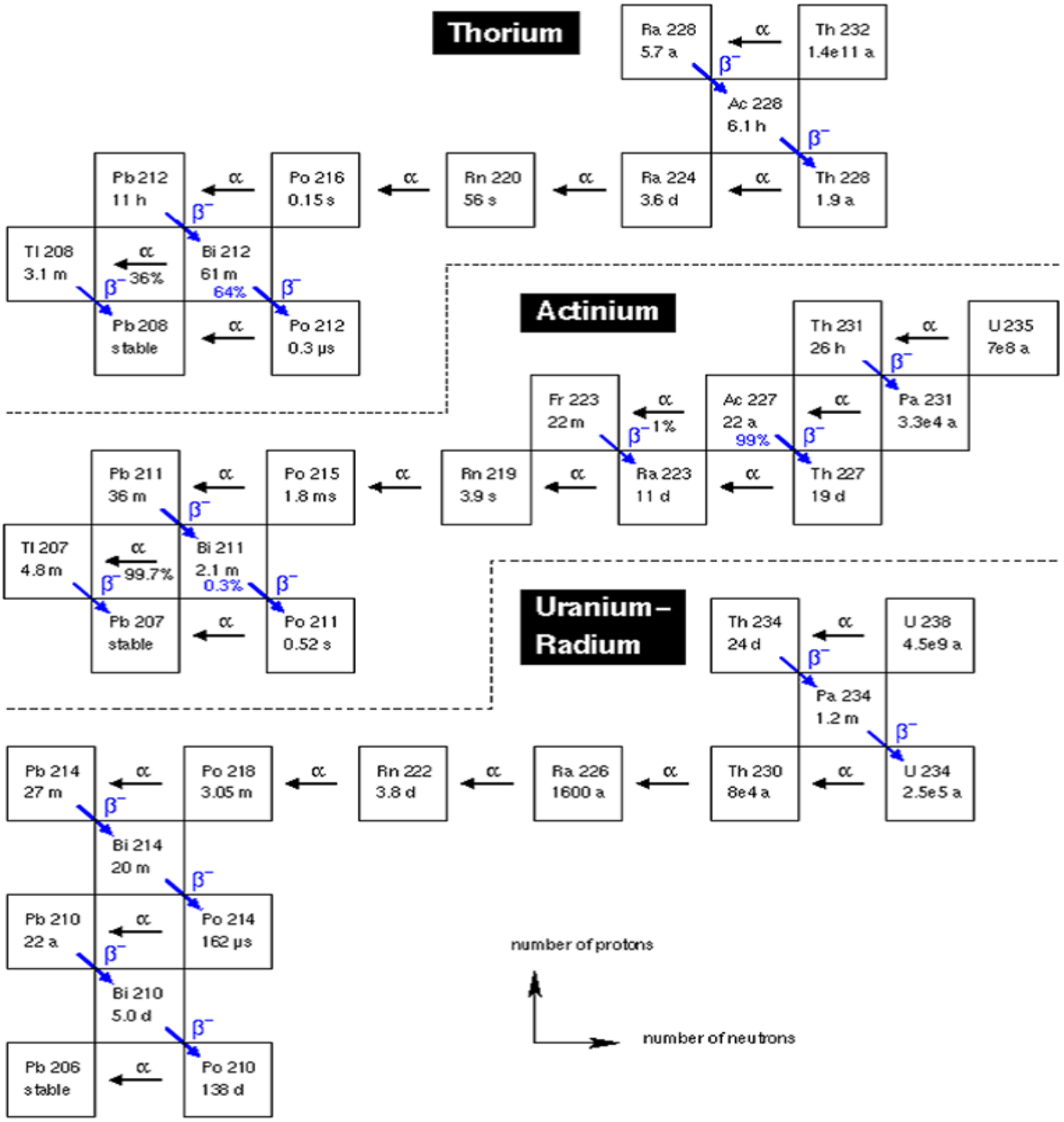

Figure (2.4): Shows the decay scheme of three nuclear chains [42].

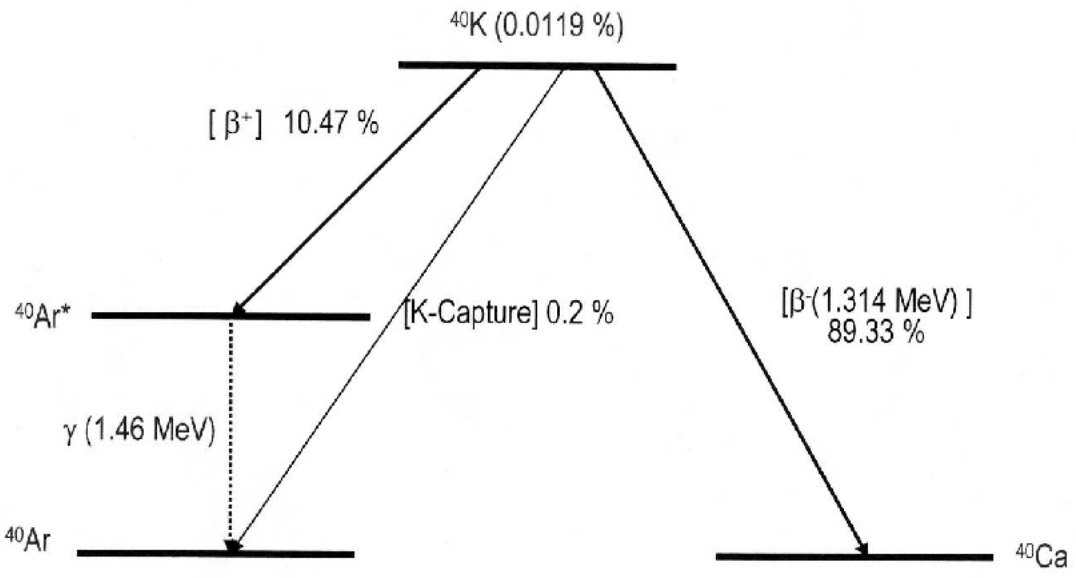

Figure (2.5) Decay Scheme of Potassium-40 [40].

2.9 Internal radiation

Radiation levels in the human body are largely influenced by uranium and the gaseous decay products of the thorium radioactive family, particularly Radon and Thoron. Rocks and soil disperse these gases, and the atmosphere also contains them at easily similar concentrations. Humans breathe them in at the decomposition stage after they have spread through the air. Similar results occur when the aforementioned gassy decay products are consumed by plants and animals. Most meals will eventually contain it, causing detectable levels of natural radiation. Normal meals and cereals have a lot of radiation, but milk products, fruit, and vegetables seem to be in a different situation because they contain little radioactivity [37].

2.10 Radon

Radon is occurring naturally, odorless, colorless, radioactive, tasteless, and a noble gas [43]. In fact, it is the heaviest noble gas in nature. Due to the relatively long half-life of radon and gaseous nature, radon can be regarded as a significant contributor to radioactivity in the atmosphere. Gaseous radon can be

produced by rocks, soil, and construction material which contain amounts of naturally occurring thorium and uranium. Radon occurs naturally as a product of the Uranium decay. Radon contributes by over 50% of the total natural radiation that human received [44]. Based on this, radon consists of a significant health hazard which leads to radon monitoring in different environments around the world. Radon is a gas, chemically inert radioactive element, boiling temperature is - 61.8ºC and its density is 9.73 kg/ m^3. It dissolves with water at a temperature of 20ºC. Its atomic number of 86 makes it a noble element and therefore both non-reactive chemically and atomically mobile at normal temperatures [45]. Also, it is highly soluble in nonpolar solvents and moderately soluble in cold water [46].

2.11 Radon of Isotopes

Radon occurs as three natural isotopes: ^{219}Rn, ^{220}Rn, ^{222}Rn, and derived from three different radioactive decay chains, commencing with ^{235}U, ^{232}Th ,^{238}U and respectively [47]. There are four ^{222}Rn short living daughters' polonium-218, lead-214, bismuth-214 and polonium-214. Two of the radon daughters are alpha emitters (polonium-218 and polonium-214) and the others are beta emitters (polonium-214 and bismuth-214) as shown in Figure (2.6) [48].

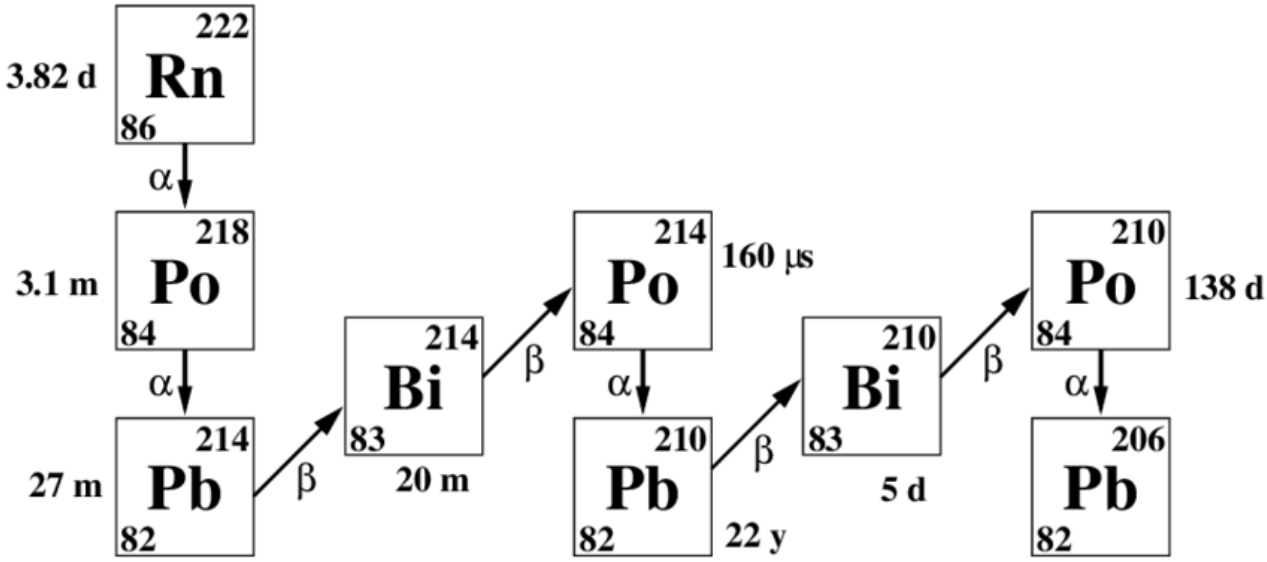

Figure (2.6) Radon decay chain [48]

2.12 Radioactive Equilibrium

Decay series occur when all radionuclides decompose, at an equivalent rate in equilibrium. There are three differing types of balance: secular equilibrium, no equilibrium, and transient equilibrium counting on whether the parent's half-life is bigger or but the daughter's half-life [49].

2.12.1 Secular equilibrium

Secular equilibrium occurs between the radioactivity of the parent nuclei and the daughter nuclei, when half-life of parent nuclei ($t_{P1/2}$) is very larger than the half-life daughter nuclei ($t_{D\ 1/2}$). It is also an ideal equilibrium where the activity of the parent nucleus (A_D or A_1) is equal to the activity of the daughter nuclei (A_P or A_2), which is at its greatest value [50], as shown in Figure (2.7). Secular equilibrium may be also expressed by writing [50]:

$$\frac{A_D}{A_P} = 1 \qquad (2.8)$$

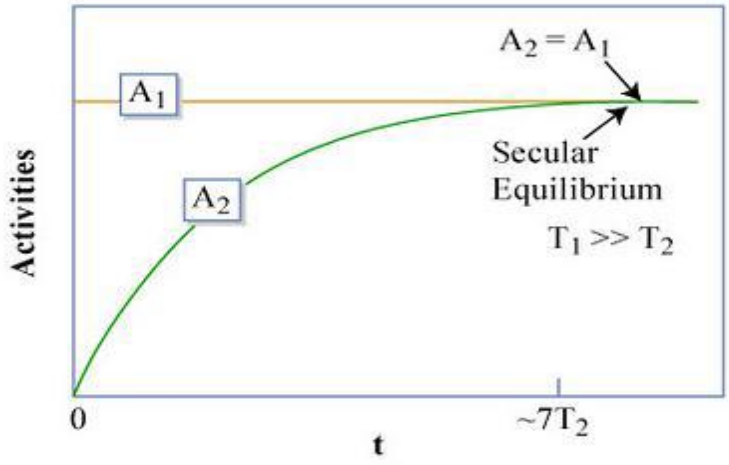

Figure (2.7): Secular equilibrium [50].

2.12.2 Transient equilibrium

When half-life of the parent the radionuclides are longer than the daughter's half-life, Transient equilibrium occurs [51] (see Figure (2.8)). The daughter's activity will increase until the activity of the parents exceeds, then the

daughter will dissolve in the half-life if the father has the same half-life. Transient equilibrium may be also expressed by writing **[**52**]**:

$$\frac{A_D}{A_P} = \frac{\lambda_P}{\lambda_D - \lambda_P} \qquad (2.9)$$

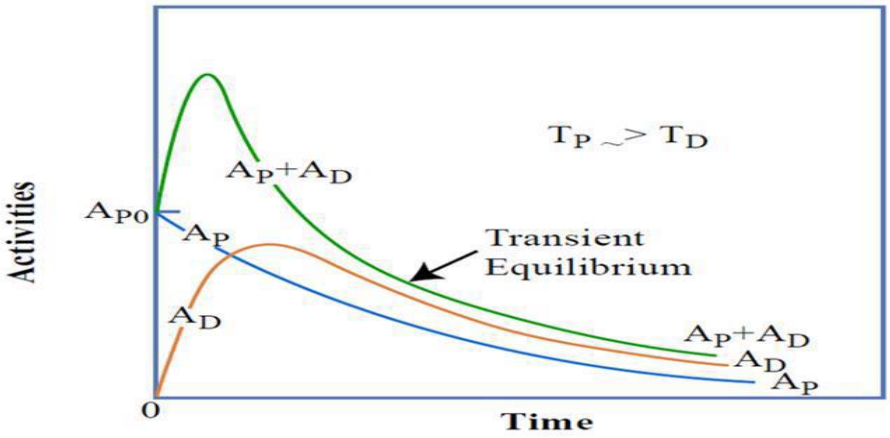

Figure (2.8): Transitional equilibrium [52].

2.13 No Equilibrium

If the half-life of the parent is less than the half-life of the daughter. No equilibrium occurs [51, 53]. The daughter's activity will increase and decrease, Parent activity decreases see Figure (2.9)

$$(t_{1/2})_1 < (t_{1/2})_2 \quad \text{Or} \quad \lambda_1 > \lambda_2 \ (\lambda_P > \lambda_D) \qquad (2.10)$$

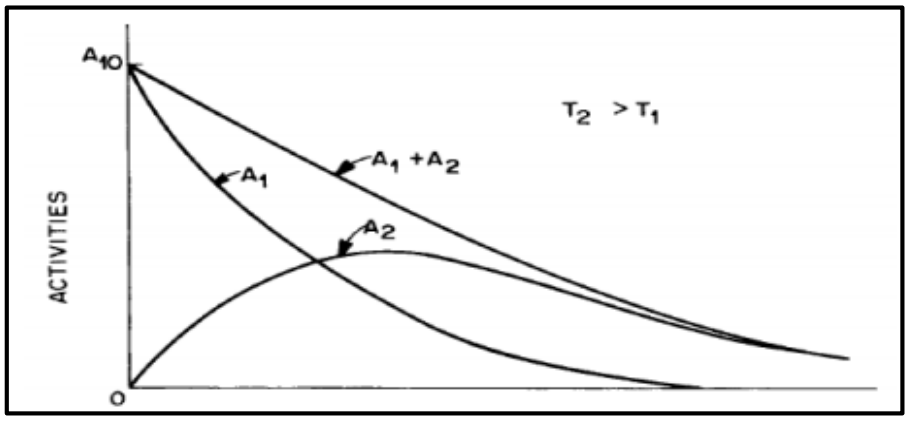

Figure (2.9): No equilibrium [53].

2.14 Radioactivity in Food

Humans are exposed to radioactive elements mostly through food consumption, which results in internal radiation doses [54,55]. Radioisotopes that occur naturally are primarily responsible for both external and internal radiation exposure in people [56]. Ingestion of food or drink, as well as the contact of other objects with the mouth [57]. The most frequent causes include poor housekeeping, a lack of personal hygiene, or allowing food intake in radioactive locations. Chemicals consumed determine their absorption and excretion as they go through the digestive system based on their solubility . Water soluble chemicals can easily travel to human organs through the bloodstream. The intestines are where insoluble chemicals pass through and are removed [58]. Thorium, uranium, and potassium are examples of terrestrial radioisotopes that mostly enter the body through food consumption and just a little amount through inhalation [56,59]. Food contamination is influenced by the kind of soil, its chemical characteristics, the physical and chemical forms of radionuclides in the soil, radionuclide uptake by particular plants, and finally the level of accumulation by particular foods [60].

2.15 Health Effect of Radiation

Cells are the basic unit of a living thing; they are complex structures contained by a surface membrane [63]. The cells' modification or death as a result of damage caused by the human body's interaction with radiation may impair tissues or organ function, resulting in a stochastic or deterministic effect [66]. On living cells, radiation can have both indirect and direct biological effects. Ionizing radiation induces excitation in the same molecule, the direct effect occurs as it is deposited and absorbed directly affecting the (DNA) molecules by primary radiation, direct ionization of atoms in the (DNA) molecules by Compton reactions in the target tissues, and the photoelectric effect is the result

of energy absorption. Bonds that can break one or both of the (DNA) strands will be broken if this energy is sufficient to remove electrons from the molecule [64].

2.16 Nuclear Detectors

The instrument which used to detect the nuclear particles or radiation are called Nuclear radiation detectors. These are based on the principle of excitation or ionization of atoms of medium in which the incident charged particles pass through [65].

2.16.1 Scintillation detectors

Scintillates are one of the oldest types of radiation detector because measurements could be made with photographic film. Images could be collected or intensity measurements could be made. Measurements were also made with the human eye observing the brightness of frequency of flashes in the scintillator. Nowadays the light output is converted into voltage pulses that are processed in the same way as pulses from proportional counters, semiconductor detectors etc.

The purpose of scintillation detectors is that we want to produce a large light output in the visible range .There are two commonly used types of scintillators, inorganic crystals and organic scintillators. The scintillation mechanism is different for these two types[66].

2.16.2 Solid state nuclear track detectors

A thin piece of plastic or film inside a container that detects and records charged particles is known as a solid state nuclear track detector (SSNTD), also known as drilled path detectors, alpha track detectors (ATD), or dielectric track detectors (DTD) [67]. Long radon monitoring periods are the main purpose for it. A wide variety of materials get ionized when heavy charged particles pass through an intermediate [68]. The construction of a barrier of small channels

(damaged tracks), which are usually discovered at the conclusion of the measurement time, is caused by the passage of heavy ionizing nuclear particles through the majority of solid materials. In order to automatically count the detectors using a counting device, they are submerged in a caustic solution that highlights the damaged channels [69]. Many ideas have been presented to explain how ionizing particles in solids generate tracks, but none of them fully describes both organic and inorganic materials. The fundamental mechanisms of energy loss are well understood. Excitation and ionization of matter atoms cause a fast-moving charged particle to lose energy. In any solid, ionization forms charge centers. Further excitation and ionization can be caused by the expelled electrons, commonly known as X-rays . Free radicals are produced when deexcitation breaks down long molecular chains in organic compounds like polymers. The ion starts to gather electrons as it slows down, lowering its charge. The main source of energy loss close to the route's end is atomic collisions rather than electronic collisions. Atomic collisions result in atom displacement and vacancy formation. A graphic representation of the formation of the track in a crystal and a polymer is shown [70].The number of tracks per unit area is proportional to the amount of Radon in the air. The pits are circular if the particles enter the detector's surface at normal incidence; otherwise, they are elliptical. The direction of incidence is indicated by the orientation of the elliptical pit opening [71].

3.1 Introduction

Natural radioactivity (gamma and alpha emitters) has sparked widespread interest around the world, particularly in Iraq, due to its vital role in people's safety. The goal of this study was to determine the concentration of gamma and alpha emitters in spices samples , that collected from several Iraqi markets .This chapter is focused on the collected samples, preparation of samples, the preparation of the devices and theoretical equations that using in calculating. Figure (3-1) depicts the study's framework.

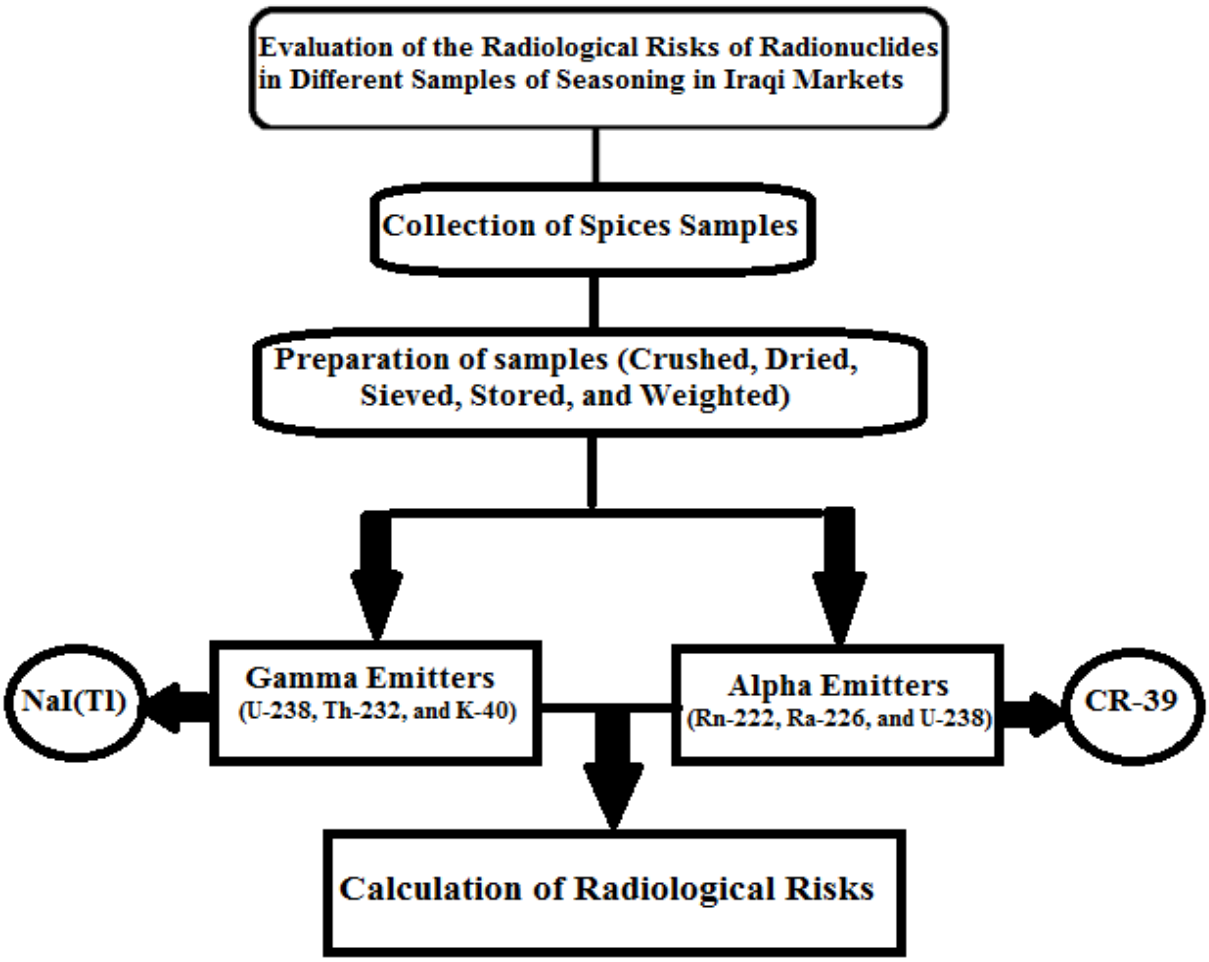

Figure (3-1): A schematic diagram of the main parts of the current study.

3.2 Collection of the Samples

This study includes 57 samples of various spices varieties that were gathered from several Iraqi markets between 1/11/2021 to 1/12/2021. The full details of the spice samples, including sample code, sample type, and Original, are presented in the tables (3-1).

Table (3-1): Information of spices samples in the present study.

No.	Sample code	Sample Name	Original
1	A1	Turmeric	India
2	A2	Coriander	Syria
3	A3	Mint	Iraq
4	A4	Cumin	India
5	A5	Cinnamon	Indonesia
6	A6	Kafta Spice	India
7	A7	Black pepper	India
8	A8	Paprika	India
9	A9	Basil	Syria
10	A10	Sumac	Syria
11	A11	Aniseed	Nigeria
12	A12	Thyme	Syria
13	A13	Ginger	Nigeria
14	A14	Mace	Sri Lanka
15	A15	Parsley	Syria
16	A16	Rosemary	Iran
17	A17	Fenugreek	India
18	A18	Curry	India
19	A19	Powder chives	China
20	A20	Nigella seed	Syria
21	A21	Salad spice	Iraq
22	A22	Kebab spice	Iraq
23	A23	Powder chives	Iran
24	A24	Oats	Iraq
25	A25	Grill spice	Iraq

26	**A26**	Chicken spice	Saudi Arabia
27	**A27**	Meat Maggi	Iraq
28	**A28**	Parsley	Iraq
29	**A29**	Cress seed	Iraq
30	**A30**	Dill	Iraq
31	**A31**	Kabsa spice	Saudi Arabia
32	**A32**	Soup spice	Syria
33	**A33**	Meat Mandi spice	Yemen
34	**A34**	Salt	Iraq
35	**A35**	Marjoram	India
36	**A36**	Biryani spice	India
37	**A37**	Soda	Iraq
38	**A38**	Linseed	India
39	**A3**	Dried lemon	USD
40	**A40**	Chamomile	India
41	**A41**	White pepper	India
42	**A42**	Hot pepper	India
43	**A43**	Mustard	India
44	**A44**	Rocca	India
45	**A45**	Clove	Pakistan
46	**A46**	Picked Spice	Egypt
47	**A47**	Sweet bean	Syria
48	**A48**	Gory roses	Syria
49	**A49**	Nutmeg	Indonesia
50	**A50**	Roselle	India
51	**A51**	Kibbeh Spice	Iraq
52	**A52**	Lick rice	Egypt
53	**A53**	Sagebrush	Palestine
54	**A54**	Onion Powder	Iraq
55	**A55**	Alum	Palestine
56	**A56**	Banging	Iraq
57	**A57**	Chicken Mandi Spice	Yemen

3.3 Preparation of the Samples

The samples were put in a plastic bag and tagged with their names, sample codes, and countries of origin. The following are the six steps in sample preparation:

1. The samples were cleaned.

2. Sun-dried at a temperature of (40 to 42)^{o}C.

3. Used an electronic mill to crush the samples, as shown in Figure (3-2a).

4. As shown in Figure, sieved using a sieve with a pore size of 0.8 mm (3-2b).

5. Manually balance a 1 kg weight as shown in Figure (3-2c).

6. To examine the secular equilibrium between ^{226}Ra and ^{222}Rn, store the spice samples for at least a month in Marinelli beakers (1 litter for measuring gamma emitters and a plastic container for measuring alpha

Figure (3-2): Devices used to preparation of samples for the present study.

3.4 Nuclear Systems of Measurement Used in This Study

The gamma-ray spectroscopy system with scintillation detector NaI(Tl) of (3"×3") crystal dimension and solid-state nuclear track detectors made by TASTRAK (CR-39) are the two approaches employed in this investigation as follows:

3.4.1 Gamma-ray Spectroscopy

3.4.1.1 NaI(Tl) Detection System

NaI(Tl) system, as shown in Figure (3-3), was used which consists of a scintillation detector NaI(Tl) of (3"×3") crystal dimension, supplied by (Alpha Spectra, Inc.-12I12/3), coupled with a multi-channel analyzer (MCA) (ORTEC –Digi Base) with range of 4096 channel joined with ADC (Analog to Digital Convertor) unit, through interface. The spectral data was converted directly to thePC of the laboratory introduced using (Maestro-32) software [72]. Finally, the spectral data was converted directly to the PC of the laboratory.

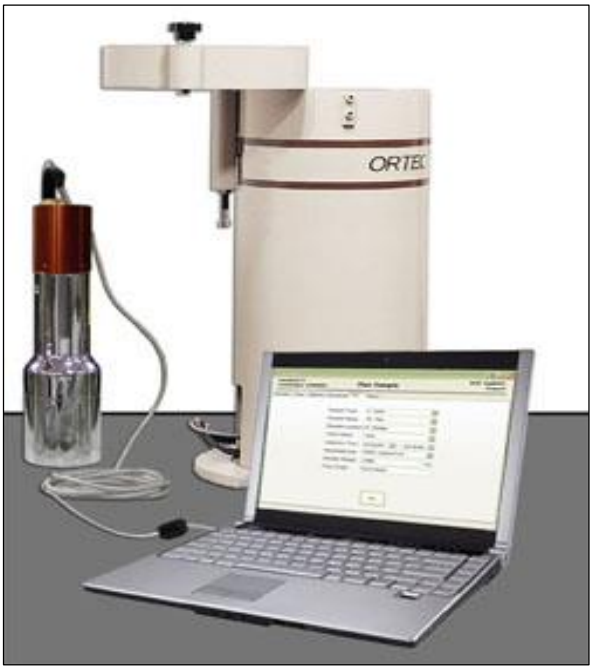

Figure (3-3): NaI (TI) (3 "× 3") detector system

The detector is kept vertical and sheltered by an ORTEC cylindrical chamber to lessen background radiation. The shielding consists of two pieces, the upper one

being a cover that is 5 cm thick and 22 cm in diameter that surrounds the crystal and is made of lead that is 5 cm thick and 20 cm long. The bottom portion serves as the basis [72]. The photograph of the shielding is shown in Figure (3-4) .

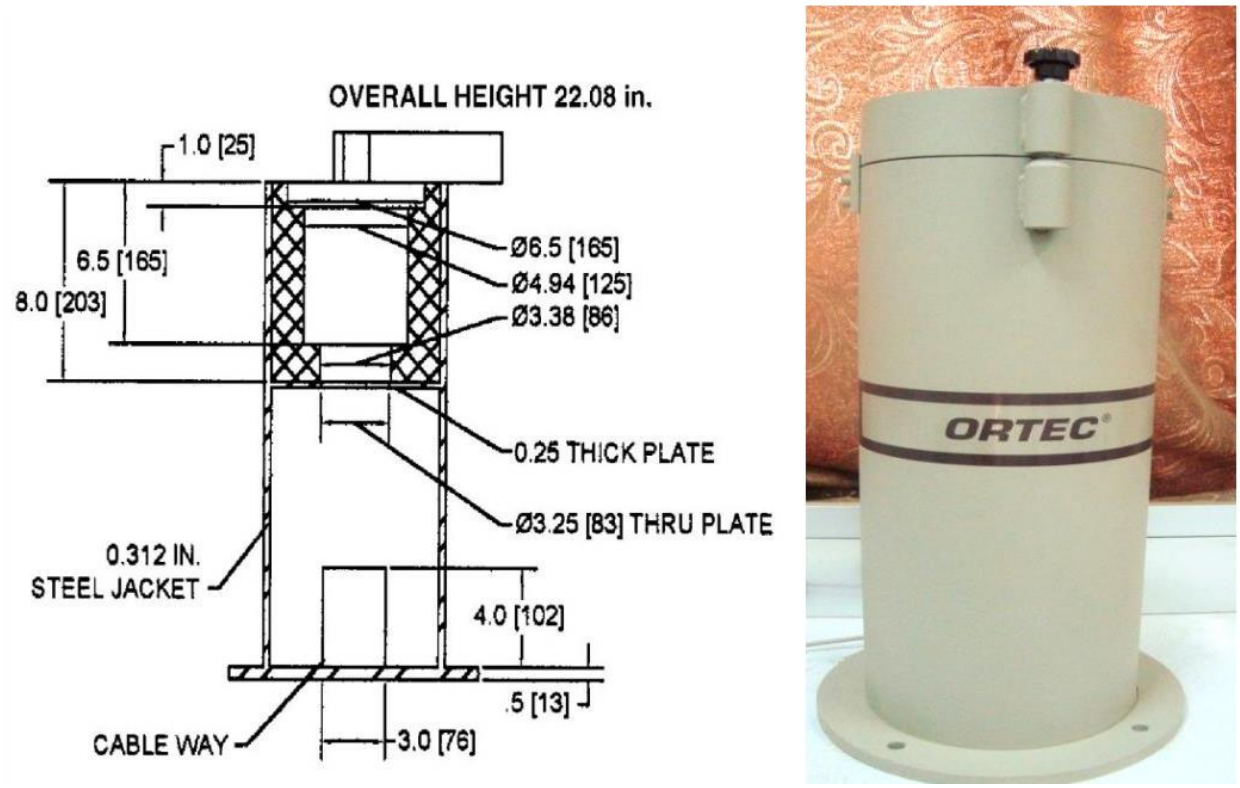

Figure (3-4): Photograph of the shielding chamber in NaI(Tl) detector [72].

To minimize the effect of the scattered radiation from the shield, the detector is located at the center of the chamber, as shown in figure (3.5) [72].

Figure (3.5): Detector position in the shielding[72].

3.4.1.2 Energy Calibration for NaI (Tl) Detector

The calibration of energy for gamma- ray spectroscopy is a relationship between the number of channels in a multichannel analyzer and gamma photon energy, which is critical for determining a form for radioactivity nuclides[73,74]. Calibration of energy in the present study can be carried out using five stander sources of gamma- ray such as ^{137}Cs, ^{60}Co,^{22}Na, ^{54}Mn, and ^{152}Eu that product from USNRC and State License Expert Quantities, "Gamma Source Set", Model RSS–8.

The energy calibration curve is shown in Figure (3-**6).**

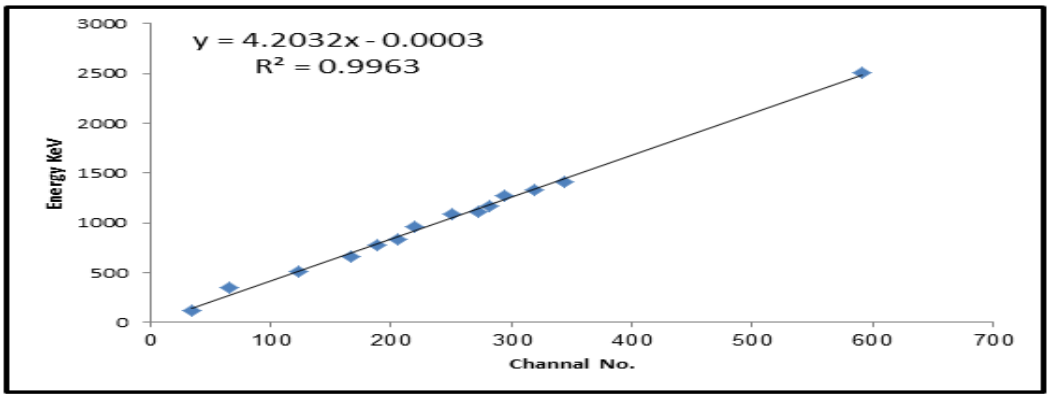

Figure (3-6): Energy Calibration Curve of NaI(TI) 3"×3"

From the energy calibration figure the relation between channel and energy is linear and mathematically represented by the equation [74]:

Energy(keV)=4.2032*(Channal No.)-0.0003 (3.1)

3.4.1.3 Energy Resolution

The energy resolution is the detector's capacity to distinguish between two peaks with a minimal energy difference [75]. The following equation can be used to determine resolution [76]:

$$\textbf{Energy Resolution=FWHM/Ch} \times \textbf{(100\%)} \qquad \textbf{(3.2)}$$

Where 'FWHM' is the full width at half maximum for photo peak of the spectrum of gamma rays source and Ch is channel number at the centroid the gamma peak. The value obtained in this work was (7.9%) ^{137}Cs standard source that energy 661.66 keV,, as shown in Figure (3-7)

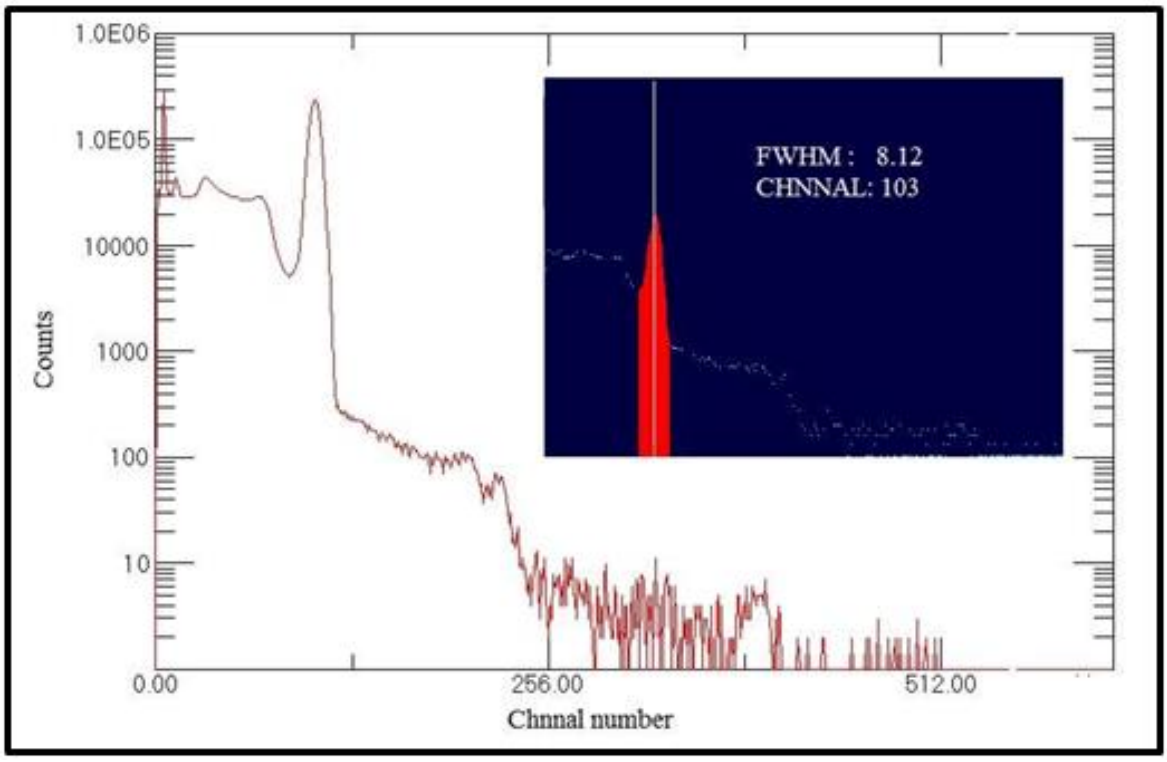

Figure (3-7): Spectrum of ^{137}Cs using (Maestro-32)

3.4.1.4 Detector Efficiency

The ratio of the number of particles or photons recorded by the detector to the number of particles released by the source is known as detection efficiency[77]. The following relation is used to calculate the efficiency of the detector measuring system for a specific energy[75,76] :

$$\varepsilon = \frac{Cp}{I\gamma\ t.A} \times (100\%) \qquad (3.3)$$

where Iγ is the transition probability of the emitted gamma-ray (see table (3-8)), A is activity sources at the time of the experiment, and Cp is the count (area) under the given energy peak after background removal. From equation(3-4) can be used to determine the activity of the standard source[78] .

$$A = A_o e^{-\lambda \Delta t} \qquad (3.4)$$

Where A_o denotes each source's initial activity (Bq) at time t_o, A denotes the source's activity (Bq) at time t, λ denotes the decay constant, and ($\Delta t = t-t_o$). Four sources ^{137}Cs, ^{60}Co, ^{22}Na, ^{54}Mn, and ^{152}Eu as shown in Figure (3-8),were used to calibrate the variation in the absolute photo-peak detector efficiency with gamma-ray energy .

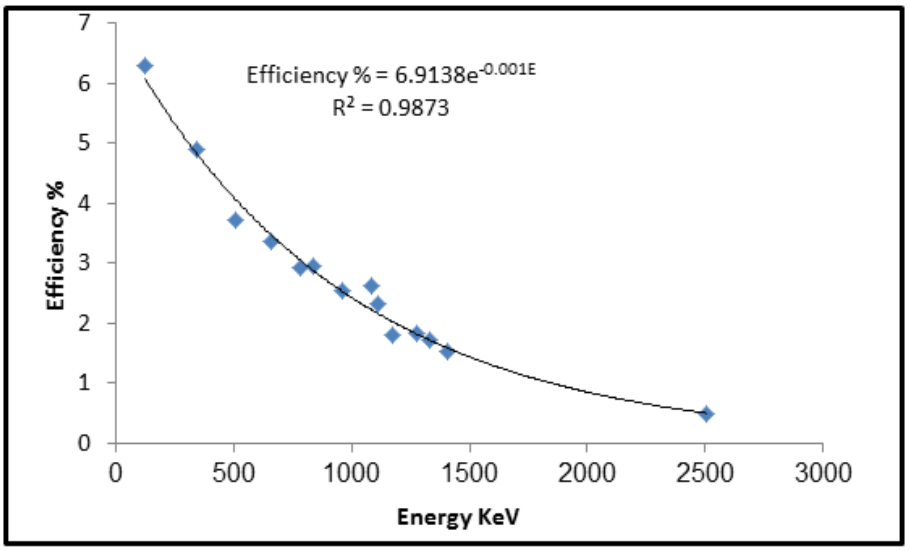

Figure (3-8): The efficiency calibration curve of NaI (Tl) (3"×3")

The exponential correlation (98.73 %) from Figure(3-9)was discovered to be as follows :

$$\varepsilon = 6.9138\, e^{-0.001\, E(kev)} \qquad (3.5)$$

From the equation (3-5), it is possible to determine the efficiency in, ^{214}Bi (^{238}U or ^{226}Ra) ,^{40}K and ^{208}Ti(^{232}Th).

Table (3-2): Characteristics of the sources used in the present study [75**]**

Isotopes	Activity (μCi)	Energy (keV)	Serial number	Production date	I_γ %
^{137}Cs	1	661.66	IRS-126	1/1/2009	85.21
^{60}Co	1	1173.24	IRS-141	1/1/2009	99.9
		1332.5			99.88
^{22}Na	1	511	IRS-139	1/2/2009	181
		1274			99.95
^{54}Mn	1	834	IRS-128	1/1/2009	100
^{152}Eu	0.9	1407	IRS-149	1/11/2009	24
		1112			16.4
		1085.8			10
		964			17.3
		778.9			15.2
		344.3			31.4
		121.8			33.2

3.4.1.5 Gamma Radiation Measurement

The Marinelli was placed on the NaI(Tl) detector (around the detector) at time 5 hour to get the gamma-ray spectrum after the spice samples had been kept in plastic Marinelli cups with a capacity of (1) liter (Figure 3-9).

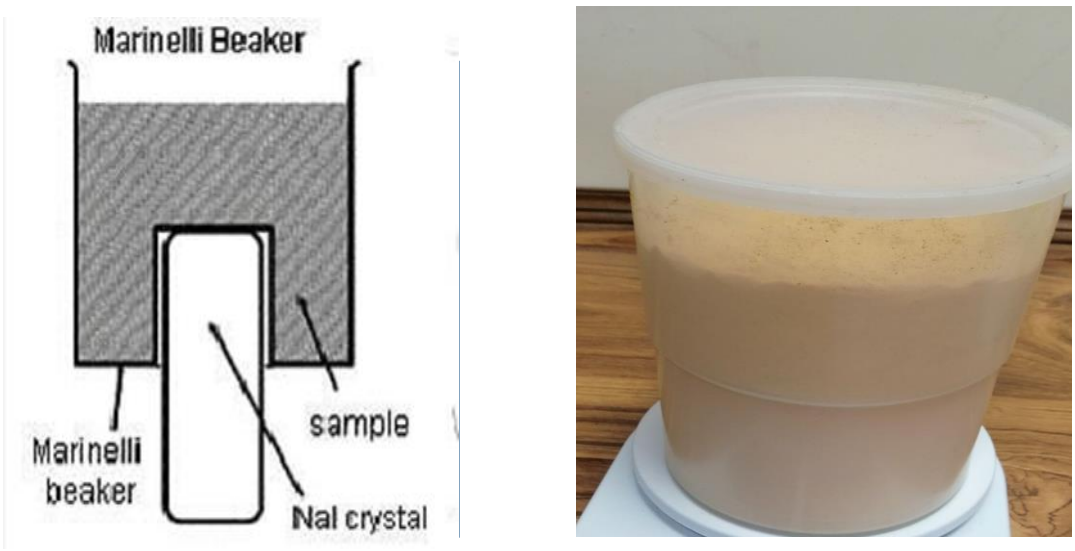

Figure (3-9): Sample of spice in marinelli beaker.

Using the MAESTRO-32 information examination package, the net zone under the contrasting photograph tops is calculated in the energy range by deducting the check due to background sources from the net zone of a particular top. All measurement techniques document background radiation resulting from cosmic rays, natural radioactivity in earth materials, structural materials within the system, and construction materials outside the system. This background varies from location to location and is influenced by the detector's size, quality, and kind of shield. Due to its interaction with the system's shield, the radiation background will grow. Utilizing capacity empty (1L) polyethylene plastic Marinelli, the background range is calculated. Due to the NaI(TI) detector's limited resolution, containers on the indicator and monitoring in the meantime for the sample estimations are necessary at low gamma energies where photo-peaks aren't well-isolated [78]. This makes it possible to measure specific activity concentrations (Bq/kg) at well-separated photo peaks at high energies, such as the one found in our results from the gamma beams generated by the progenies of (^{232}Th) and (^{238}U), which are in harmony with them, while (^{40}K) was specifically evaluated by its gamma-line at 1460 KeV. (^{40}Ar). Therefore, the (1764 KeV) gamma-lines were used to determine the specific activity of

(^{238}U) (^{214}Bi) [79]. Similar results have been calculated of (^{232}Th) were identified using the gamma-ray lines 2614 KeV (^{208}Tl) , as shown in Figure (3-10) and(3.11) .

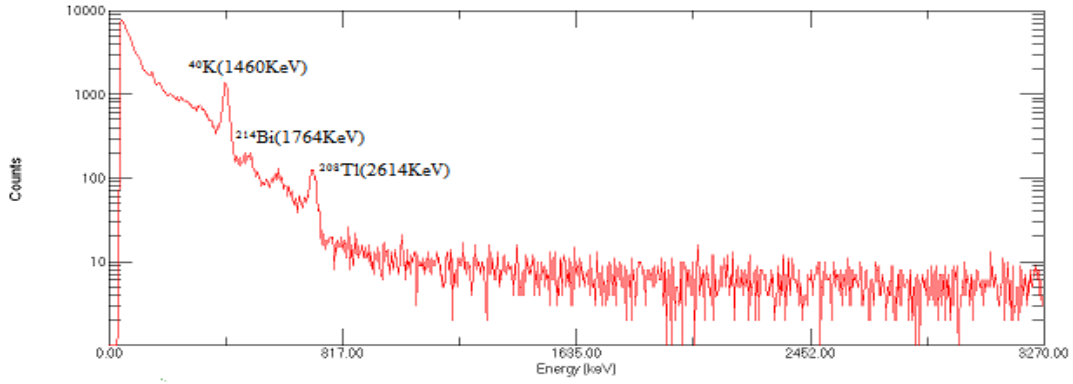

Figure (3-10): The spectrum of sample A11 (Aniseed origin of Nigeria) in Maestro-32

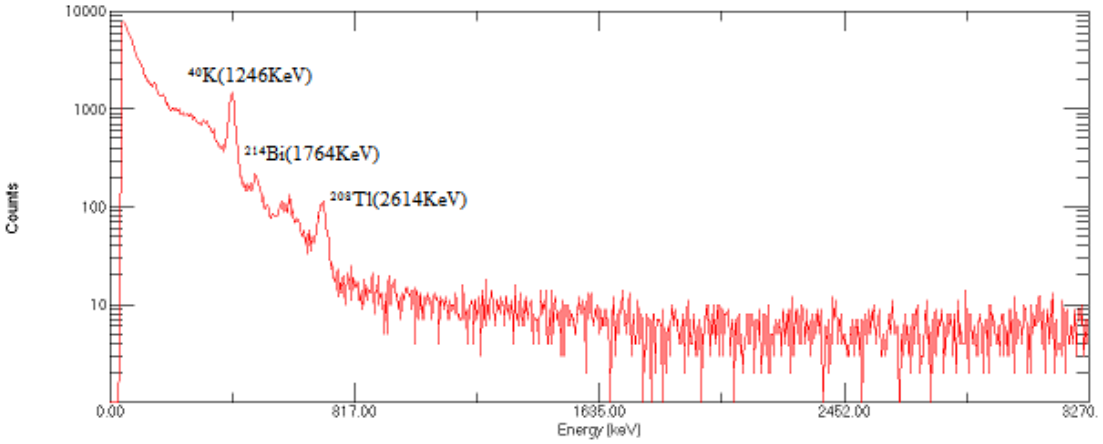

Figure (3-11): The spectrum of sample A40 (Chamomile origin of India) in Maestro-32

3.4.2 Solid State Nuclear Tracks

3.4.2.1 CR-39 Detection System

The track methodology used the same collecting and processing of spices samples as the NaI(Tl) approach. Each sample were assigned a unique code in order to differentiate them. TASTRAK Analysis System, Ltd., UK: TASTRACK sold the detector CR-39 ($C_{12}H_{18}O_7$). A CR-39 detector sheet had dimensions of (2.5cm×2.5cm), a thickness of 1mm, and a code for each sheet that suited the TASL image system. The sheet has a density of almost 1.32 grams per cubic meter.

3.4.2.2 Sample container

The sample name and storage date were inscribed on the sealed can techniques, which had dimensions of 7 cm high and 5 cm in average diameter. The plastic container utilized in this investigation is shown in Figure (3-12). The detectors (CR-39) were adhered to the upper section of the containers using adhesive tape, and the containers were subsequently filled with spice samples of varying thickness (h=3.5 cm), as well as the distance between the sample and the detector (L=3.5 cm). The samples in the present study were kept for 90 days. After the irradiation period has ended, the detectors are removed from the containers and the chemical etching procedure begins.

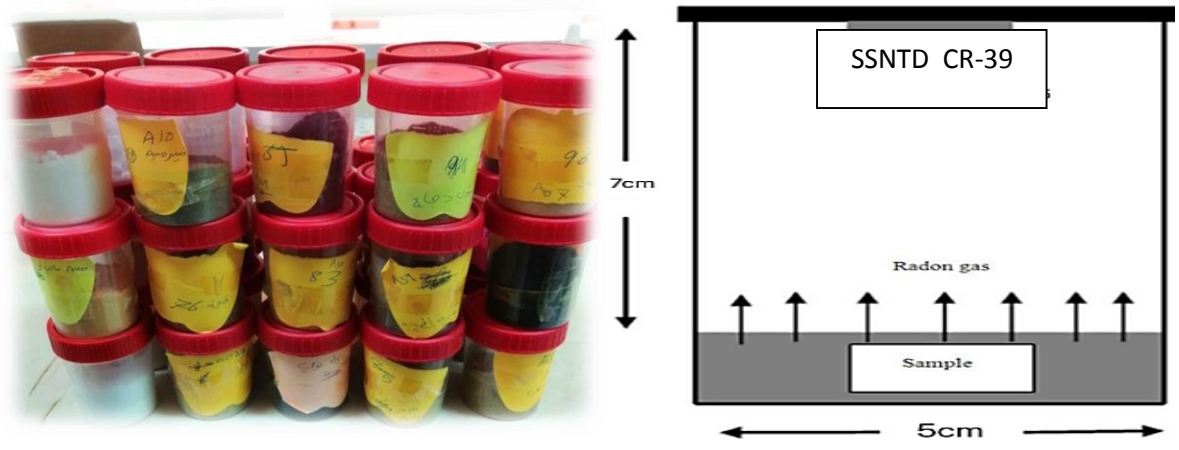

Figure (3-12): A test tube technique in the present study.

3.5.2.3 Chemical Etching

Sodium hydroxide (NaOH) solution is made by dissolving (100) gm of sodium hydroxide (NaOH) in (0.4) Litter of pure water using the equation [80]:

$$W = W_{eq} \times N \times V \qquad \textbf{(3.6)}$$

Where W denotes the weight of NaOH required to create the specified normalcy, W_{eq} is weight equivalent for NaOH, N denotes the normalcy, and V is distilled water volume.

The etching solution is prepared using an HS-860 magnetic stirrer (Lab companion Magnetic Stirrer, Ceramic Top 110 volt 60 Hz) as illustrated in Figure (3-13) and stored for (24) hours until homogenous. Detectors are carefully removed from the plastic containers during this time. with special attention paid to preserving the detectors surfaces free of scratches[81].

Figure (3-13): Magnetic stirrer (HS-860, made in the USA)

Next day CR-39 detectors were placed in a solution of NaOH at 6.25 N and put Pyrex in a HH-1 electrical water bath whose it is the temperature range is between 0 to 100 ºC and it is fix its at (70 ±1) ˚C within 3 hours as shown in

Figure (3-14). Finally, the detectors were taken out of the solution and thoroughly cleaned with distilled water before being dried with soft tissue paper.

Figure (3-14): Water bath

3.6 Theoretical Equitation

3.6.1 Gamma-ray Emitters

The specific activity (A) was estimated using to the equation [82,83]:

$$A\left(\frac{Bq}{kg}\right) = \frac{(N-B)}{t \times \varepsilon \times I_\gamma \times m} \qquad (3.7)$$

where, N and B are the areas under photo peak for samples and background, respectively. t is counting time (18000 sec), ε is the efficiency of the detector, Iγ is the probability of gamma emission, and m is the mass of sample.

Equation (3.8) was used to calculate Radium Equivalent Activity (Ra_{eq}) [84]:

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_U + 1.43A_{Th} + 0.077A_K \qquad (3.8)$$

Where A_U, A_{Th}, and A_K are the specific activity in ^{238}U, ^{232}Th, ^{40}K, respectively.

Internal hazard index (H_{in}) was estimated using the equation [85]:

$$H_{in}\left(\frac{Bq}{kg}\right) = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (3.9)$$

The annual effective dose (AED) in foods containing natural radionuclides that depend on annual consumption rate(I), specific activity (A), and dose conversion factor (CF_i) was determined using equation [86]:

$$\boldsymbol{AED\left(\frac{mSv}{y}\right) = I \times \sum_{i}^{3} A_i \times CF_i} \qquad (\mathbf{3.10})$$

The values of dose conversion factor (Sv/Bq) for ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K were 2.80E-07, 2.30E-07, and 6.20E-09, respectively that taken from UNSCER publication .

The threshold consumption rate (DI_{thresh}) is defined as the amount of the consumption of drinking water and food substances by a human who leads to an acceptable limit of annual effective dose (Eave.; 0.320) [86]. DI_{thresh} in food samples of the present study was determined using to the equation [87]:

$$\boldsymbol{DI_{thresh}\left(\frac{Kg}{y}\right) = \frac{E_{ave}}{\sum_{i}^{3} A_i \times CF_i}} \qquad (\mathbf{3.11})$$

In this work, for simplicity of analysis, ICRP, (1990) assumed parameter was used. Fatal cancer risk was estimated from effective dose obtained using the International Commission on Radiological Protection cancer risk assessment methodology (ICRP, 2007) as stated in equation (3.12).Fatal Cancer Risk (FCR) depends on annual effective dose value, and was calculated form the following relation [82]:

$$\boldsymbol{FCR = H_E \times DL \times RF} \qquad (\mathbf{3.12})$$

where H_E stands for optimal dose (mSv/y), DL for life expectancy (70 y), and RF for fatal risk factor , which is set at 0.05 per Sievert [82].

The HCR is hereditary cancer risk, for stochastic effects ICRP uses a value of 0.04 for the public as risk factor (ICRP, 1991) [87]:

$$\boldsymbol{HCR = AED \times DL \times RF} \qquad (\mathbf{3.13})$$

3.6.2 Alpha-particles Emitters

The activity concentration of (^{222}Rn) in the airspace of the tube **(C)** using CR-39 detector (produced from TASTRAK company (Ltd.,UK: TASTRACK) and developed by TASL) was calculated from the formula [88]:

$$C\left(\frac{Bq}{m^3}\right) = \frac{\rho}{K\,t} \qquad (3.14)$$

where **ρ** is the track density on the exposed detector (Tr/cm^2), **t** is the exposure time of the sample (90 d), and *K* is calibration factor for CR-39 detectors which was equal to (0.28±0.043) Track.cm^{-2} /Bq.m^{-3}.day.

Can be calculated the concentration of radon within the sample **(C_{Rn}),** the following relation was used [89]:

$$C_{Rn}\left(\frac{Bq}{m^3}\right) = \frac{C\,\lambda_{Rn}\,h\,t}{l} \qquad (3.15)$$

where λ_{Rn} is the decay constant of ^{222}Rn (0.1814 d^{-1}), h represents the distance from the sample surface to the detector, **t** represents the exposure time (90 d), and l represents the thickness of the sample in the tube.

The specific activity of radon inside sample **(C_{Rn})** was determined using the relation [89]: $$C_{Rn}\left(\frac{Bq}{kg}\right) = \frac{C\,l\,A}{M} \qquad (3.16)$$

where A represents the surface area of the sample and **M** is the mass of the sample that was investigated.

The specific activity of radium (^{226}Ra) within the sample **(C_{Ra})** was determined according to effective time (T_e), using the relationship [90]:

$$C_{Ra}\left(\frac{Bq}{kg}\right) = \frac{\rho}{K\,T_e}\frac{h\,A}{M} \qquad (3.17), \quad \text{where } T_e = \left[T - \lambda_{Rn}^{-1}\left(1 - e^{-\lambda_{Rn}T}\right)\right]$$

The radon activity inside the sample **(A_{Rn})** was obtained using the following formulas [91]:

$$A_{Rn}(Bq) = C_{Rn}\,V \qquad (3.18), \qquad V = \pi\,l\,r^2 \qquad (3.19)$$

where V is the sample volume in m^3.

The number of uranium (^{238}U) atoms in the sample (N_U) at the secular equilibrium can be obtained by [92]:

$$N_U = \frac{A_{Rn}}{\lambda_U} \qquad (3.20)$$

where λ_U is the decay constant of uranium (4.9×10^{-18}/s). Therefore, the uranium weight in the sample (M_U) in gram can be determined as follows [93]:

$$M_U = \frac{N_U A_U}{N_A} \qquad (3.21)$$

where A_U is the mass number of ^{238}U and N_A is Avogadro's number. Thus, the concentration of uranium **(C_U)** in ppm (where 1ppm=12.35 Bq/kg) is given by:

$$C_U(ppm) = \frac{M_U}{M} \qquad (3.22)$$

The annual average internal dose AAIED by an ingestion of radionuclides has been calculated according to the equation [94]:

$$AAIED\left(\frac{nSv}{y}\right) = C_i \times I \times CF \qquad (3.23)$$

where ***I*** represent the rate of consumption from the spices intake for an individual within a year (kg/y), and CF represents the effective dose conversion factor of the radioactive element, the effective dose conversion factor for radon, radium and uranium ingestion by people as 3.5 nSv/Bq , 280 nSv/Bq and 45 nSv/Bq [95].

The risk of an excess cancer fatality per million people (RECFPMP) as a result of consuming radon, radium, and uranium from food samples has been computed using the following formula [96,97]:

$$\mathbf{RECFPMP} = AAIED \times DL \times RF \qquad (3.24)$$

where RF is the risk factor (0.055 Sv^{-1}) advised by the ICRP and DL is the life expectancy (70 yr). [98].

4.1 Introduction

The outcomes of the two experiments that were carried out for this study are provided in this chapter. 57 different samples of spices (seasoning) from Iraqi markets were examined for gamma emitters (^{238}U, ^{232}Th, and ^{40}K) and alpha emitters (^{222}Rn, ^{226}Ra, and ^{238}U) using NaI(Tl) detectors. The results of the radiological hazard index owing to alpha and gamma emitters in the same study samples were also included in this chapter. It also entails presenting the key findings, advice, and suggested next steps before reviewing the findings with the international standards for gamma and alpha emitters. The results will be split between gamma and alpha emitters as follows: :

4.2 Results of Gamma Emitters

The results of gamma-ray in 57 types of different samples of spices (seasoning) in Iraqi markets using the sodium iodide detector, as well as radiological hazards are listed, as follows:

4.2.1 Specific Activity

Different samples of spices from Iraqi markets were examined for the specific activity of the radionuclides ^{238}U, ^{232}Th, and ^{40}K, and their radiation hazard parameters are reported in Table (4.1). The specific activity is taken from Table (4.1). for ^{238}U ranged from 6.01±0.64 Bq/kg in sample A52 to 27.92±2.20 Bq/kg in sample A13 with an average value of 12.052±1.247Bq/kg. However, the specific activity for ^{232}Th varied from 3.32± 0.40 Bq/kg in sample A5 to 14.84 ± 0.86Bq/kg in sample A49 with an average value of 8.760±0.650 Bq/kg. In addition, the values of ^{40}K ranged from 106.69 ± 2.83 Bq/kg in sample A11 to 472.94 ± 11.59Bq/kg in sample A40 with an average value of 256.924±5.966 Bq/ kg.

Table (4-1): Results of ^{238}U, ^{232}Th, and ^{40}K in spices samples in the present study.

No.	Sample Code	Specific Activity Bq/Kg					
		^{238}U		^{232}Th		^{40}K	
		Average	S.D	Average	S.D	Average	S.D
1	A1	15.94	1.78	11.71	0.93	268.33	7.64
2	A2	7.50	0.97	9.09	0.65	424.24	7.61
3	A3	11.62	1.28	3.85	0.45	241.57	6.11
4	A4	8.98	1.02	4.88	0.46	422.10	7.33
5	A5	12.44	1.28	3.32	0.40	180.54	5.08
6	A6	10.72	1.07	7.87	0.56	312.66	6.05
7	A7	12.36	1.65	8.51	0.83	397.50	9.78
8	A8	10.09	1.19	9.42	0.70	198.38	5.51
9	A9	12.58	1.30	8.19	0.64	230.41	5.83
10	A10	18.33	1.50	3.86	0.42	289.95	6.22
11	A11	6.82	0.69	5.19	0.36	106.69	2.83
12	A12	20.15	1.70	11.63	0.78	228.99	6.00
13	A13	27.92	2.20	7.00	0.67	397.02	8.66
14	A14	14.58	1.39	11.14	0.74	245.34	5.95
15	A15	14.65	1.82	13.24	1.05	318.91	8.85
16	A16	9.78	1.06	7.27	0.55	328.92	6.42
17	A17	14.95	1.51	10.25	0.76	267.36	6.67
18	A18	14.47	1.27	9.72	0.63	283.26	5.86
19	A19	16.80	1.42	8.02	0.59	284.34	6.10
20	A20	10.96	1.18	8.70	0.64	342.01	6.89
21	A21	12.78	1.31	8.69	0.66	177.62	5.10
22	A22	10.94	1.19	7.42	0.59	229.83	5.68
23	A23	20.11	1.78	5.71	0.57	409.15	8.37

24	A24	16.84	1.75	7.18	0.69	235.09	6.81
25	A25	13.18	1.35	10.13	0.72	238.66	6.01
26	A26	9.03	1.00	4.24	0.41	134.83	4.02
27	A27	9.65	1.03	7.81	0.56	291.62	5.90
28	A28	6.29	0.72	7.42	0.47	114.38	3.21
29	A29	7.12	0.90	9.53	0.63	148.89	4.32
30	A30	13.79	1.37	12.46	0.79	167.76	4.97
31	A31	14.41	1.40	5.14	0.51	277.96	6.42
32	A32	14.01	1.43	8.20	0.66	205.23	5.71
33	A33	8.91	0.78	3.73	0.31	131.22	3.14
34	A34	18.38	1.62	11.12	0.77	341.08	7.31
35	A35	11.02	1.15	8.57	0.61	381.36	7.06
36	A36	9.99	1.13	8.60	0.64	224.40	5.60
37	A37	8.90	1.06	14.01	0.81	414.26	7.58
38	A38	7.49	0.94	9.21	0.63	126.18	4.05
39	A39	12.49	1.26	9.83	0.68	257.50	5.54
40	A40	11.84	1.26	9.68	0.69	472.94	11.59
41	A41	10.17	1.14	8.84	0.65	135.53	2.85
42	A42	14.30	1.50	7.04	0.64	201.13	4.83
43	A43	11.95	1.47	12.89	0.93	164.23	3.74
44	A44	12.35	1.31	9.07	0.68	376.38	6.94
45	A45	8.26	0.95	7.68	0.56	114.45	3.39
46	A46	7.46	0.90	8.54	0.59	246.52	5.50
47	A47	7.37	0.78	5.87	0.42	258.17	5.81
48	A48	10.57	1.10	9.23	0.62	119.17	3.67
49	A49	11.49	1.25	14.84	0.86	369.28	8.84
50	A50	13.05	1.33	14.17	0.84	314.28	7.13
51	A51	14.45	1.45	11.30	0.78	311.56	6.84

52	A52	6.01	0.64	5.00	0.36	309.54	7.23
53	A53	9.91	1.19	14.18	0.86	129.38	4.07
54	A54	9.82	1.08	8.40	0.61	258.84	5.81
55	A55	8.20	1.02	8.42	0.63	108.28	2.80
56	A56	15.26	1.39	12.61	0.77	210.83	4.81
57	A57	7.02	0.91	9.13	0.63	264.39	6.05
Average ±S.D		12.052±1.247		8.760±0.650		256.924±5.966	
Minimum Maximum		6.01±0.64 27.92±2.20		3.32± 0.40 14.84 ± 0.86		106.69 ± 2.83 472.94±11.59	
Worldwide average [UNSCEAR] [99]		33		45		420	

The average specific activity of ^{238}U, ^{232}Th, and ^{40}K is 33 Bq/kg, 45 Bq/kg, and 420 Bq/kg, respectively, according to the UNSCEAR (2008) recommended standard [99]. According to the findings in Table (4.1), all values of ^{238}U for the particular activities were lower than the global average activity, which was the recommendation made by UNSCEAR in 2008. While the UNSCEAR 2008 report contained all values for the ^{232}Th specific activity. As well as, it is clear for ^{40}K, that the specific activities, with the exception of A2,A40 samples were only found to be higher than the worldwide average (420 Bq/kg).

4.2.2 Radiological Effects

The results of $\mathbf{Ra_{eq}}$ and $\mathbf{H_{in}}$ in spices samples are seen in Table (4-2). From Table (4-2), $\mathbf{Ra_{eq}}$ was ranged from a high value (68.5) Bq/kg in the sample of A13 to a low value (22.5) Bq/kg in sample A11 and the average is (44.315) Bq/kg. While, $\mathbf{H_{in}}$ was ranged from high value (0.260) in the sample of A13 to (0.086) in sample A28 and average is (0.152).

Table (4-2): Results of Ra_{eq}, H_{in} in spices samples in present study

No.	Sample Code	Ra_{eq} (Bq/kg)	H_{in}
1	A1	53.3	0.187
2	A2	53.2	0.164
3	A3	35.7	0.128
4	A4	47.9	0.154
5	A5	31.1	0.118
6	A6	46.0	0.153
7	A7	55.1	0.182
8	A8	38.8	0.132
9	A9	42.0	0.148
10	A10	46.2	0.174
11	A11	22.5	0.079
12	A12	54.4	0.201
13	A13	68.5	0.260
14	A14	49.4	0.173
15	A15	58.1	0.197
16	A16	45.5	0.149
17	A17	50.2	0.176
18	A18	50.2	0.175
19	A19	50.2	0.181
20	A20	49.7	0.164
21	A21	38.9	0.140
22	A22	39.2	0.136
23	A23	59.8	0.216
24	A24	45.2	0.168
25	A25	46.0	0.160
26	A26	25.5	0.093

27	A27	43.3	0.143
28	A28	25.7	0.086
29	A29	32.2	0.106
30	A30	44.5	0.158
31	A31	43.2	0.156
32	A32	41.5	0.150
33	A33	24.3	0.090
34	A34	60.5	0.213
35	A35	52.6	0.172
36	A36	39.6	0.134
37	A37	60.8	0.188
38	A38	30.4	0.102
39	A39	46.4	0.159
40	A40	62.1	0.200
41	A41	33.2	0.117
42	A42	39.9	0.146
43	A43	43.0	0.149
44	A44	54.3	0.180
45	A45	28.1	0.098
46	A46	38.7	0.125
47	A47	35.6	0.116
48	A48	32.9	0.118
49	A49	61.1	0.196
50	A50	57.5	0.191
51	A51	54.6	0.187
52	A52	37.0	0.116
53	A53	40.1	0.135
54	A54	41.8	0.139

55	A55	28.6	0.099
56	A56	49.5	0.175
57	A57	40.4	0.128
Average		44.315	0.152
Minimum		22.5	0.086
Maximum		68.5	0.260
Global limits		370[100]	1[101]

The results of health impacts (**AED, DI_{thres}, HCR and FCR)** in spices samples are seen in Table (4-3). From Table (4-3), **AED** for ^{238}U was ranged from (0.003) mSv/y in the sample of A11,A28 and A52 to (0.014) mSv/y in the sample of A13 and the average is (0.0060) mSv/y.While, **AED** for ^{232}Th was ranged from (0.001) mSv/y in the sample of A5 to (0.006) mSv/y in the sample of A37,A49,A50 and A53 and the average is (0.0036) mSv/y. Also from Table (4-3), **AED** for ^{40}K was ranged from (0.001) mSv/y in the sample of A11, A28, A33, A45, A48, A53 and A55 to (0.005) mSv/y in the sample of A2,A4,A23,A37 and A40 and the average is (0.0028) mSv/y. $\mathbf{AED_{Total}}$ was ranged from (0.007) mSv/y in sample A11 and A33 to (0.021) mSv/y in sample A13 and Average is (0.0128) mSv/y. While, $\mathbf{DI_{thresh}}$ was ranged from (26.9) kg/y in the sample of A13 to (85.0) kg/y in sample A11 and Average is (53.917) kg/y. Also from Table (4-3), $\mathbf{HCR\times10^{-3}}$ was ranged from (0.019) the sample of A11 to (0.060) in sample A13 and Average is (0.0351) and the $\mathbf{FCR\times10^{-3}}$ was ranged from (0.024) the sample of A11 to (0.075) in sample A13 and Average is (0.0439).

Table (4-3): Results of AED, DI_{thresh}, HCR and FCR in spices samples in the present study

No.	Samp Code	AED mSv/y			AED_{Total} mSv/y	DI_{threh} (kg/y)	HCR $\times 10^{-3}$	FCR $\times 10^{-3}$
		^{238}U	^{232}Th	^{40}K				
1	A1	0.008	0.005	0.003	0.016	36.3	0.044	0.056
2	A2	0.004	0.004	0.005	0.012	46.9	0.034	0.043
3	A3	0.006	0.002	0.003	0.010	56.8	0.028	0.036
4	A4	0.005	0.002	0.005	0.011	51.6	0.031	0.039
5	A5	0.006	0.001	0.002	0.010	59.6	0.027	0.034
6	A6	0.005	0.003	0.003	0.012	47.4	0.034	0.043
7	A7	0.006	0.004	0.004	0.014	40.6	0.040	0.050
8	A8	0.005	0.004	0.002	0.011	51.4	0.031	0.039
9	A9	0.006	0.003	0.003	0.012	46.8	0.034	0.043
10	A10	0.009	0.002	0.003	0.014	40.9	0.039	0.049
11	A11	0.003	0.002	0.001	0.007	85.0	0.019	0.024
12	A12	0.010	0.005	0.003	0.018	32.9	0.049	0.061
13	A13	0.014	0.003	0.004	0.021	26.9	0.060	0.075
14	A14	0.007	0.005	0.003	0.015	39.2	0.041	0.051
15	A15	0.007	0.005	0.004	0.016	35.1	0.046	0.057
16	A16	0.005	0.003	0.004	0.012	49.6	0.033	0.041
17	A17	0.008	0.004	0.003	0.015	39.0	0.041	0.052
18	A18	0.007	0.004	0.003	0.014	39.8	0.041	0.051
19	A19	0.008	0.003	0.003	0.015	38.5	0.042	0.052
20	A20	0.006	0.004	0.004	0.013	44.5	0.036	0.045
21	A21	0.006	0.004	0.002	0.012	47.9	0.034	0.042
22	A22	0.006	0.003	0.003	0.011	51.7	0.031	0.039
23	A23	0.010	0.002	0.005	0.017	33.8	0.048	0.060
24	A24	0.008	0.003	0.003	0.014	40.9	0.039	0.049
25	A25	0.007	0.004	0.003	0.013	42.7	0.038	0.047
26	A26	0.005	0.002	0.002	0.008	73.7	0.022	0.027
27	A27	0.005	0.003	0.003	0.011	50.7	0.032	0.040
28	A28	0.003	0.003	0.001	0.008	76.6	0.021	0.026
29	A29	0.004	0.004	0.002	0.009	62.6	0.026	0.032
30	A30	0.007	0.005	0.002	0.014	41.2	0.039	0.049
31	A31	0.007	0.002	0.003	0.012	46.1	0.035	0.044
32	A32	0.007	0.003	0.002	0.013	45.2	0.036	0.045
33	A33	0.004	0.002	0.001	0.007	76.8	0.021	0.026
34	A34	0.009	0.005	0.004	0.018	32.6	0.049	0.062

35	A35	0.006	0.004	0.004	0.013	43.1	0.037	0.047
36	A36	0.005	0.004	0.003	0.011	51.9	0.031	0.039
37	A37	0.004	0.006	0.005	0.015	38.6	0.042	0.052
38	A38	0.004	0.004	0.001	0.009	64.0	0.025	0.031
39	A39	0.006	0.004	0.003	0.013	43.5	0.037	0.046
40	A40	0.006	0.004	0.005	0.015	37.8	0.043	0.053
41	A41	0.005	0.004	0.002	0.010	55.9	0.029	0.036
42	A42	0.007	0.003	0.002	0.012	46.6	0.035	0.043
43	A43	0.006	0.005	0.002	0.013	43.7	0.037	0.046
44	A44	0.006	0.004	0.004	0.014	40.6	0.040	0.050
45	A45	0.004	0.003	0.001	0.009	66.8	0.024	0.030
46	A46	0.004	0.004	0.003	0.010	57.3	0.028	0.035
47	A47	0.004	0.002	0.003	0.009	63.8	0.025	0.032
48	A48	0.005	0.004	0.001	0.010	55.0	0.029	0.037
49	A49	0.006	0.006	0.004	0.016	35.9	0.045	0.056
50	A50	0.007	0.006	0.004	0.016	36.1	0.045	0.056
51	A51	0.007	0.005	0.003	0.015	37.3	0.043	0.054
52	A52	0.003	0.002	0.003	0.009	67.3	0.024	0.030
53	A53	0.005	0.006	0.001	0.012	46.8	0.034	0.043
54	A54	0.005	0.003	0.003	0.011	50.9	0.032	0.040
55	A55	0.004	0.003	0.001	0.009	65.3	0.025	0.031
56	A56	0.008	0.005	0.002	0.015	37.7	0.043	0.053
57	A57	0.004	0.004	0.003	0.010	56.1	0.029	0.036
Average		0.0060	0.0036	0.0028	0.0128	53.917	0.0351	0.0439
Minimum Maximum		0.003 0.014	0.001 0.006	0.001 0.005	0.007 0.021	26.9 85.0	0.019 0.060	0.024 0.075
Global limits					0.32[90]		4×10^{-2} (ICRP,1991)	2.5×10^{-3} [102,103]

4.3 Results of Alpha Emitters

The results of alpha emitters in 57 types of spices samples using the CR-39 (solid nuclear trace detectors), as well as and radiological hazards are listed, as follows:

The results of natural alpha emitters (^{222}**Rn**, ^{226}**Ra**, and ^{238}**U**) in spices samples are seen in Table (4-4). From Table (4-4) the range of $\mathbf{C_a}$ was from (0.12Bq/m^3)

in A1 to (12.82Bq/m^3) in A12 and the average value (8.021) Bq/m^3, while the range of C_{Rn} from (1.94 Bq/m^3) in A1 to (209.26 Bq/m^3) in A12 and the average value (130.947) Bq/m^3. while the range of C_{Rn} from(0.00400 Bq/kg) in A1 to(0.43092 Bq/kg) in A11 the average value was(0.258 Bq/kg). The range of C_{Ra} was (0.00025 mBq/kg) in A1 to (0.02639 mBq/kg) in A12 and the average was (0.0164mBq/kg), while the range of C_U was from (0.00032ppm) in A1 to (0.03417ppm) in A12 and the average value was (0.0213) ppm, the range of C_U from (0.00392Bq/kg) in A1 to (0.42203Bq/kg) in A12 with average value (0.264 Bq/kg).

Table (4-4): Results of Radon, Radium and Uranium in spices samples in the present study

No.	Sample code	^{222}Rn			^{226}Ra	^{238}U	
		C_a (Bq/m^3)	C_{Rn} (Bq/m^3)	C_{Rn} (Bq/kg)	C_{Ra} (mBq/kg)	C_U (ppm)	C_U (Bq/kg)
1	A1	0.12	1.94	0.00400	0.00025	0.00032	0.00392
2	A2	0.24	3.89	0.38689	0.00049	0.00063	0.00784
3	A3	1.51	24.62	0.22947	0.00311	0.00402	0.04965
4	A4	11.51	187.88	0.05070	0.02370	0.03068	0.37891
5	A5	0.71	11.66	0.06004	0.00147	0.00190	0.02352
6	A6	6.83	111.43	0.33219	0.01406	0.01820	0.22473
7	A7	1.79	29.15	0.00800	0.00368	0.00476	0.05880
8	A8	9.88	161.32	0.32152	0.02035	0.02634	0.32534
9	A9	9.56	156.13	0.10006	0.01969	0.02550	0.31489
10	A10	2.98	48.59	0.23347	0.00613	0.00793	0.09799
11	A11	6.94	113.38	0.43092	0.01430	0.01851	0.22865
12	A12	12.82	209.26	0.42959	0.02639	0.03417	0.42203
13	A13	12.74	206.02	0.13341	0.02599	0.03364	0.41550
14	A14	3.97	64.79	0.38556	0.00817	0.01058	0.13066
15	A15	11.47	187.23	0.38956	0.02362	0.03058	0.37761
16	A16	11.63	189.82	0.42825	0.02394	0.03100	0.38283
17	A17	3.8	62.84	0.05203	0.00793	0.01026	0.12674
18	A18	12.18	198.89	0.42291	0.02509	0.03248	0.40113
19	A19	11.31	184.64	0.09739	0.02329	0.03015	0.37238
20	A20	2.78	45.35	0.42558	0.00572	0.00741	0.09146
21	A21	6.27	102.36	0.42425	0.01291	0.01672	0.20644
22	A22	12.70	207.31	0.18678	0.02615	0.03386	0.41811

23	A23	5.04	82.28	0.42158	0.01038	0.01344	0.16594
24	A24	0.63	10.37	0.14809	0.00131	0.00169	0.02091
25	A25	4.40	71.91	0.02135	0.00907	0.01174	0.14503
26	A26	12.66	206.67	0.16943	0.02607	0.03375	0.41680
27	A27	5.56	90.70	0.41891	0.01144	0.01481	0.18292
28	A28	12.62	206.02	0.21079	0.02599	0.03364	0.41550
29	A29	12.58	205.37	0.40957	0.02590	0.03354	0.41419
30	A30	2.90	47.29	0.09339	0.00597	0.00772	0.09538
31	A31	12.54	204.72	0.37889	0.02582	0.03343	0.41288
32	A32	1.35	22.03	0.40824	0.00278	0.00360	0.04442
33	A33	12.50	204.07	0.12808	0.02574	0.03333	0.41158
34	A34	12.46	203.43	0.18411	0.02566	0.03322	0.41027
35	A35	12.38	202.13	0.40424	0.02550	0.03301	0.40766
36	A36	12.30	200.84	0.40290	0.02533	0.03280	0.40504
37	A37	1.23	20.08	0.04269	0.00253	0.00328	0.04050
38	A38	12.26	200.19	0.41224	0.02525	0.03269	0.40374
39	A39	6.90	112.73	0.23214	0.01422	0.01841	0.22735
40	A40	12.22	199.54	0.41091	0.02517	0.03259	0.40243
41	A41	12.18	198.89	0.40957	0.02509	0.03248	0.40113
42	A42	7.54	123.09	0.25348	0.01553	0.02010	0.24825
43	A43	5.16	84.22	0.17343	0.01062	0.01375	0.16986
44	A44	12.14	198.24	0.40824	0.02655	0.03237	0.39982
45	A45	9.96	162.61	0.33620	0.02051	0.02656	0.32796
46	A46	12.10	197.60	0.40691	0.02492	0.03227	0.39851
47	A47	12.18	198.89	0.40957	0.02509	0.03248	0.40113
48	A48	4.01	65.43	0.13475	0.00825	0.01069	0.13197
49	A49	1.79	29.15	0.06004	0.00368	0.00476	0.05880
50	A50	2.46	40.17	0.08272	0.00507	0.00656	0.08101
51	A51	12.26	200.19	0.41224	0.02525	0.03269	0.40374
52	A52	5.75	93.94	0.19345	0.01185	0.01534	0.18946
53	A53	12.02	196.30	0.40424	0.02476	0.03206	0.39590
54	A54	11.98	195.65	0.40290	0.02468	0.03195	0.39459
55	A55	11.94	195.01	0.40157	0.02460	0.03184	0.39329
56	A56	11.90	194.36	0.40023	0.02452	0.03174	0.39198
57	A57	5.60	91.35	0.18811	0 .01152	0.01492	0.18423
Average		8.021	130.947	0.258	0.0164	0.0213	0.264
Minimum Maximum		0.12 12.82	1.94 209.26	0.00400 0.43092	0.00025 0.02639	0.00032 0.03417	0.00392 0.42203
Global limits		39[94]			30[104]	11.7[31]	

The results of health impacts (**AAIED, RECFPMP**) in spices samples are seen in Table (4-5). From this Table the range of **AAIED** for **^{222}Rn** was from (0.00003 nSv/y) in A50 to (0.01314 nSv/y) in A11 and the average value was (0.0017nSv/y), while the range **AAIED** for **^{226}Ra** was from (0.00012 nSv/y) in A50 to (0.03376 nSv/y) in A11 and the average value was (0.0089 nSv/y). Also from this Table, the range of **AAIED** for **^{238}U** from (0.00032 nSv/y) in A50 to (0.04958 nSv/y) in A11 and the average value was (0.0186 nSv/y). The range of **Total AAIED** from (0.00093 µSv/y) in A7 to (0.04943µSv/y) in A12 and the average value was (0.0300 µSv/y), while the range of **RECFPMP** was from (0.0003) in A7 to (0.0174) in A11 and the average value was (0.0097).

Table (4-5): Results of AAIED and RECFPMP in spices samples in the present study.

No.	Sample code	AAIED (nSv/y)			Total AAIED (µSv/y)	RECFPMP
		^{222}Rn	^{226}Ra	^{238}U		
1	A1	0.00244	0.01194	0.03069	0.04507	0.0158
2	A2	0.00015	0.00074	0.00191	0.00280	0.0010
3	A3	0.00145	0.00708	0.01831	0.02689	0.0094
4	A4	0.00032	0.00157	0.00402	0.00591	0.0021
5	A5	0.00038	0.00185	0.00476	0.00699	0.0024
6	A6	0.00209	0.01026	0.02635	0.03870	0.0135
7	A7	0.00005	0.00025	0.00064	0.00093	0.0003
8	A8	0.00203	0.00993	0.02561	0.03761	0.0132
9	A9	0.00063	0.00309	0.00804	0.01181	0.0041
10	A10	0.00147	0.00721	0.01852	0.02720	0.0095
11	A11	0.01314	0.03376	0.04958	0.03387	0.0174
12	A12	0.00268	0.01310	0.03366	0.04943	0.0173
13	A13	0.00084	0.00412	0.01058	0.01554	0.0054

14	A14	0.00243	0.01190	0.03059	0.04492	0.0157
15	A15	0.00246	0.01207	0.03101	0.04554	0.0159
16	A16	0.00266	0.00130	0.03344	0.04911	0.0172
17	A17	0.00033	0.00161	0.00413	0.00606	0.0021
18	A18	0.00265	0.01297	0.03334	0.04896	0.0171
19	A19	0.00061	0.00301	0.00773	0.01135	0.0040
20	A20	0.00262	0.01285	0.03302	0.04849	0.0170
21	A21	0.00261	0.01281	0.03291	0.04834	0.0169
22	A22	0.00261	0.01277	0.03281	0.04818	0.0146
23	A23	0.00120	0.00589	0.01513	0.02223	0.0078
24	A24	0.00258	0.01264	0.03249	0.04772	0.0167
25	A25	0.00093	0.00457	0.01175	0.01725	0.0060
26	A26	0.00013	0.00066	0.00169	0.00249	0.0009
27	A27	0.00107	0.00523	0.01344	0.01974	0.0069
28	A28	0.00251	0.01231	0.03164	0.04647	0.0163
29	A29	0.00133	0.00651	0.01672	0.02456	0.0086
30	A30	0.00059	0.00288	0.00741	0.01088	0.0038
31	A31	0.00240	0.01174	0.03027	0.04445	0.0156
32	A32	0.00236	0.01157	0.02974	0.04367	0.0153
33	A33	0.00082	0.00399	0.01027	0.01508	0.0053
34	A34	0.00250	0.01227	0.03154	0.04632	0.0162
35	A35	0.00254	0.001244	0.03196	0.04694	0.0164
36	A36	0.00050	0.00243	0.00624	0.00917	0.0032
37	A37	0.00026	0.00128	0.00328	0.00482	0.0017
38	A38	0.00237	0.01161	0.02985	0.04383	0.0153
39	A39	0.00146	0.00717	0.01842	0.02704	0.0095
40	A40	0.00245	0.01198	0.03080	0.04523	0.0158
41	A41	0.00250	0.01223	0.03143	0.04616	0.0162

42	A42	0.00160	0.00783	0.02011	0.02953	0.0103
43	A43	0.00109	0.00535	0.01376	0.02021	0.0071
44	A44	0.00237	0.01161	0.02985	0.04383	0.0153
45	A45	0.00242	0.01186	0.03048	0.04181	0.0146
46	A46	0.00232	0.01137	0.02921	0.04290	0.0150
47	A47	0.00236	0.01157	0.02974	0.04367	0.0154
48	A48	0.00232	0.01137	0.02921	0.04290	0.0150
49	A49	0.00085	0.00416	0.01069	0.01570	0.0055
50	A50	0.00003	0.00012	0.00032	0.00047	0.0002
51	A51	0.00038	0.00185	0.00476	0.00699	0.0024
52	A52	0.00052	0.00255	0.00656	0.00964	0.0034
53	A53	0.00234	0.01149	0.02953	0.04336	0.0152
54	A54	0.00122	0.00597	0.01535	0.02254	0.0079
55	A55	0.00109	0.00535	0.01376	0.02021	0.0071
56	A56	0.00101	0.00494	0.01270	0.01865	0.0065
57	A57	0.00097	0.00474	0.01217	0.01787	0.0063
Average		0.0017	0.0089	0.0186	0.0300	0.0097
Minimum		0.00003	0.00012	0.00032	0.00093	0.0003
Maximum		0.01314	0.03376	0.04958	0.04943	0.0174
Global limits					1.2[105]	

4.4 Discussions

4.4.1 Discussion the Results of Gamma Emitters

When the specific activity of the ^{238}U, ^{232}Th, and ^{40}K spice samples in the current investigation is compared to the specific activity of global levels as reported by UNSCEAR 2008 [99], those values are 33 Bq/kg for ^{238}U, 45 Bq/kg for ^{232}Th, an420 Bq/kg for ^{40}K, respectively. according to the results of specific activity for ^{238}U, ^{232}Th, and ^{40}K in Tables (4-1), as well as Figures (4-1), (4-2),

and (4-3), it was determined that the specific activity of ^{238}U and ^{232}Th in all of the samples of the current study are within the permissible limit set by the UNSCEAR 2008, while the results value of ^{40}K in all of the samples were less than the recommended value that was given by worldwide UNSCEAR 2008, with some samples such as A2 and A40 being an exception, because peasants are using chemical fertilizers more frequently.

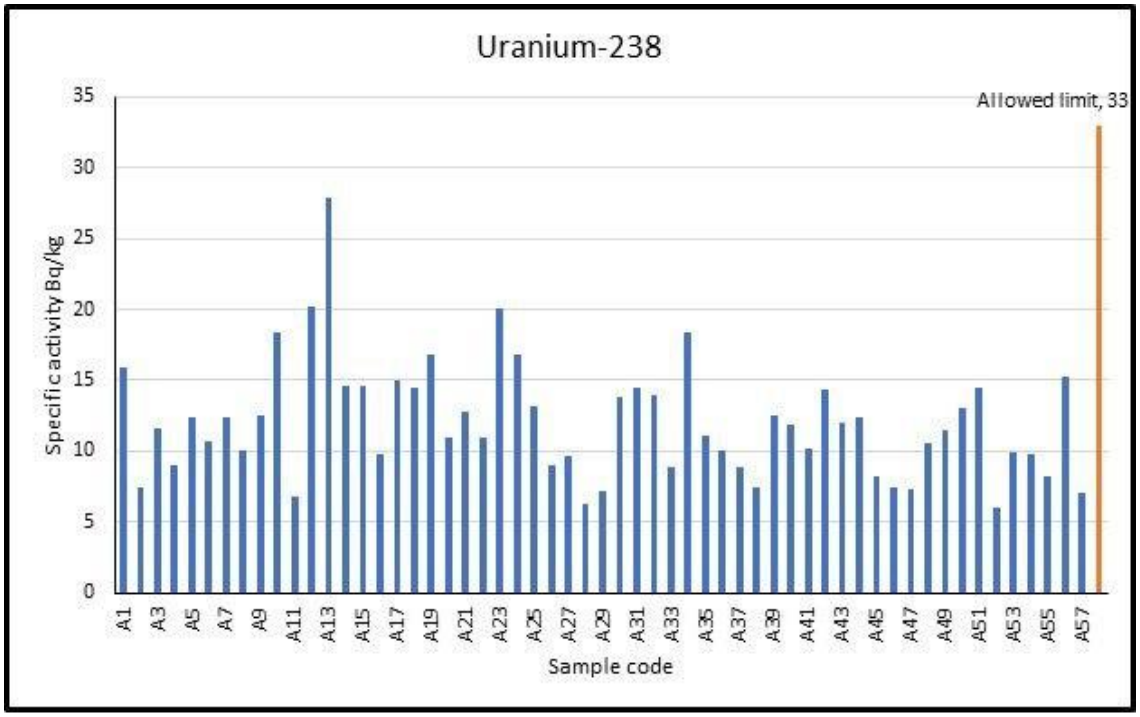

Figure (4-1): Comparing the results of ^{238}U in spices samples with global limit.

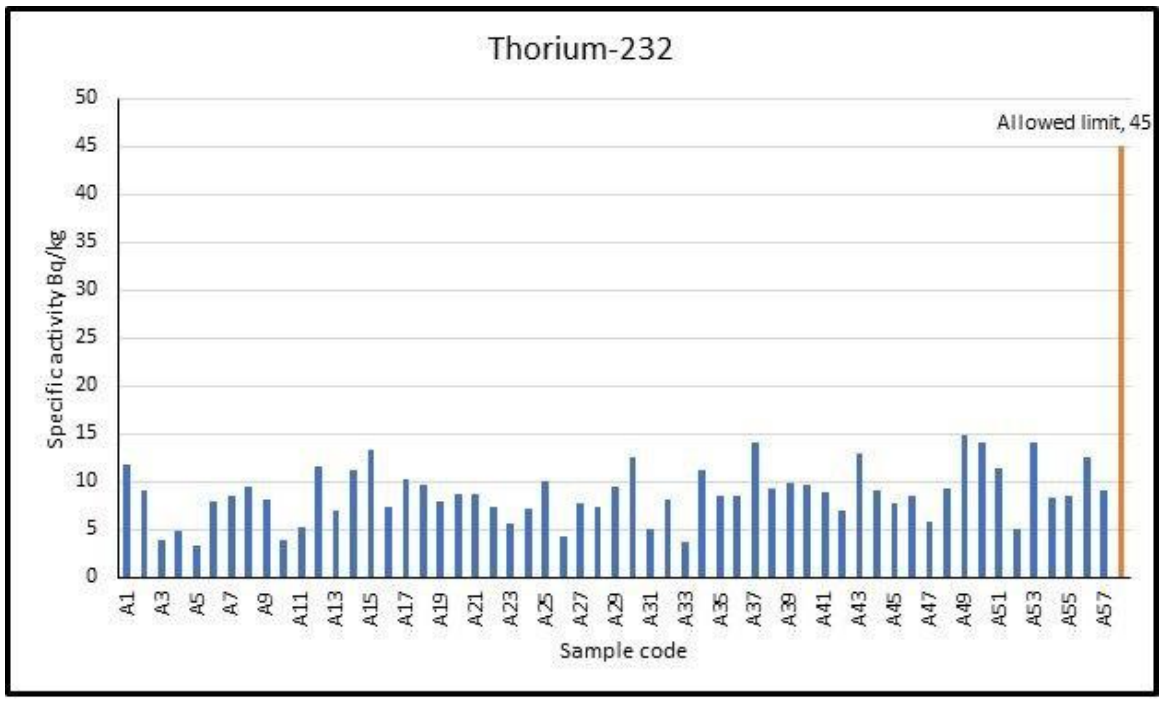

Figure (4-2): Comparing the results of ^{232}Th in spices samples with global limit.

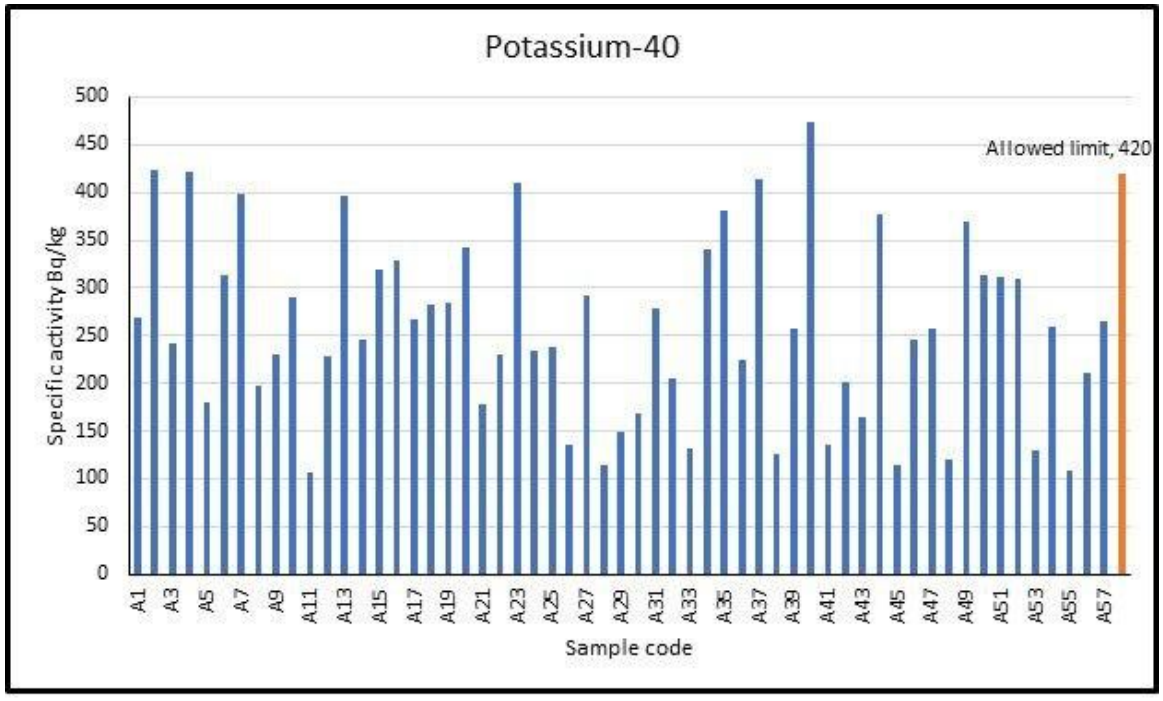

Figure (4-3): Comparing the results of ^{40}K in spices samples with global limit.

The data values for Ra_{eq} and H_{in} were fewer than 370 Bq/kg [100] and 1 [101], respectively, which is the safety stage, as shown in Tables (4-2) as well as Figures (4-4) and (4-5).

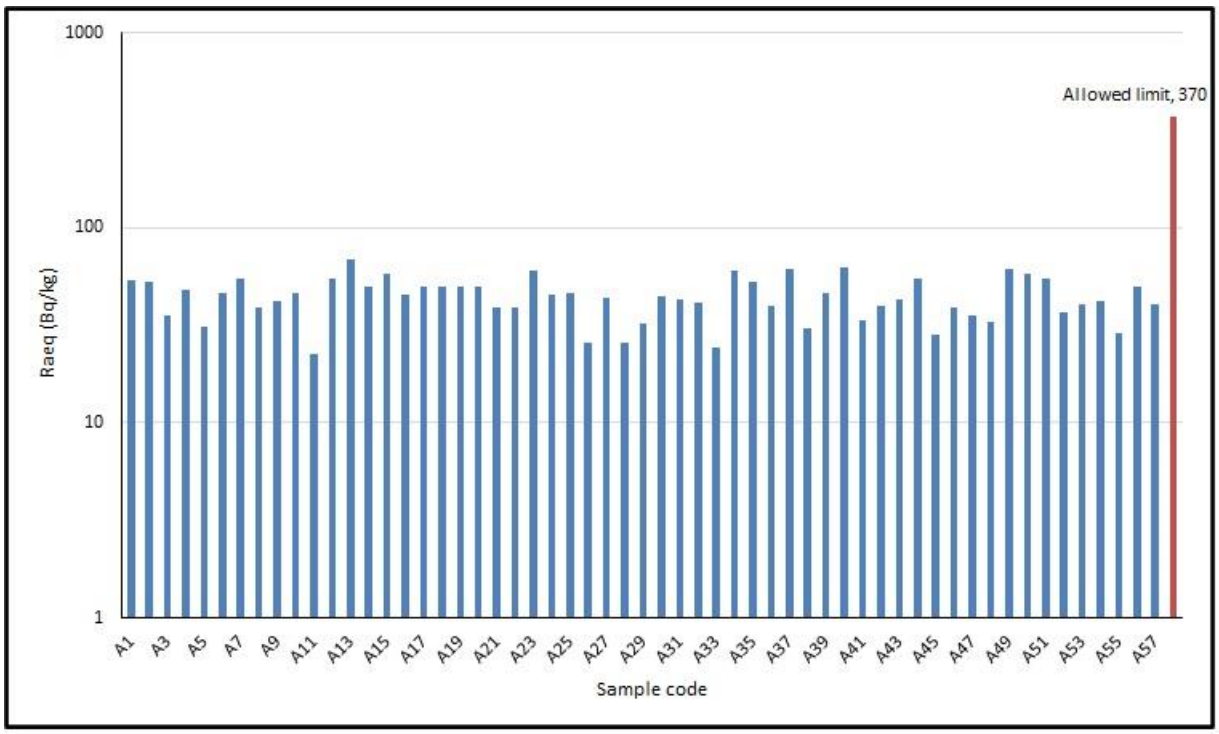

Figure (4-4): Comparing the results of Ra_{eq} in spices samples with global limit.

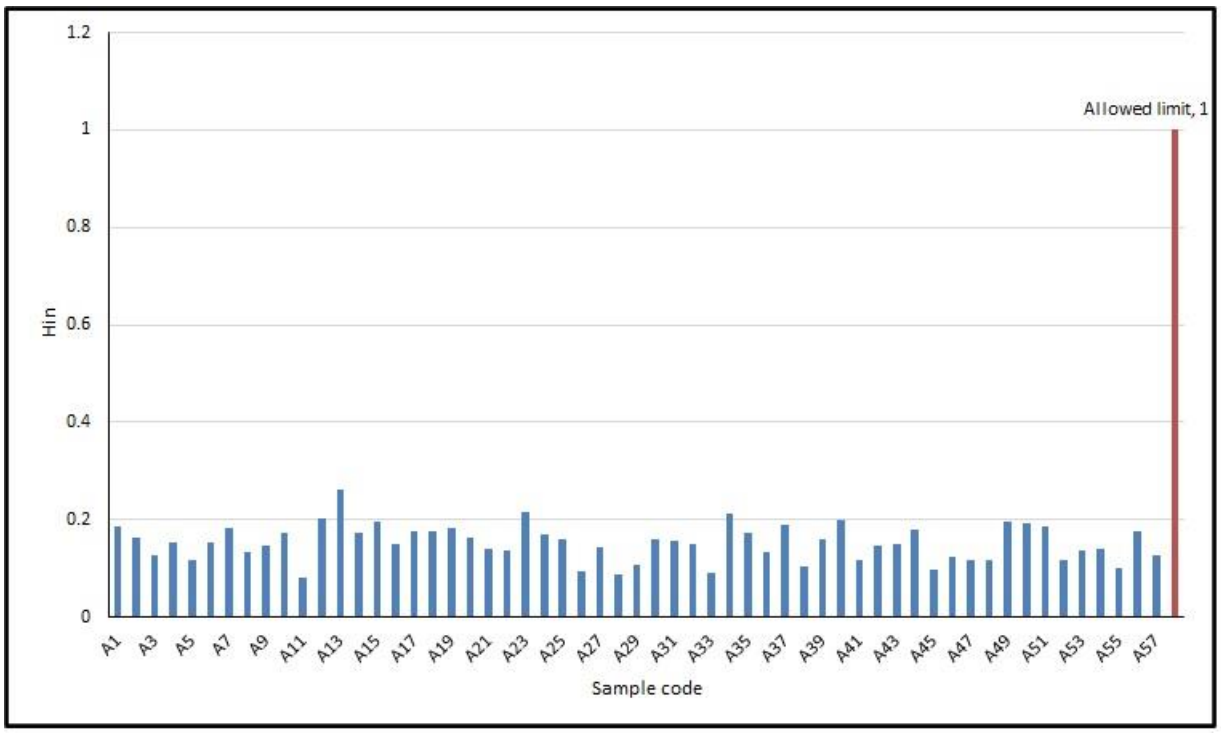

Figure (4-5): Comparing the results of H_{in} in spices samples with global limit.

From the results of Table (4-3), as well as from Figure (4-6) in the present samples, it is noted that the values of AED_{Total} of ^{40}K,$^{238}U$and ^{232}Th less than the AED_{Total} of worldwide levels according to UNSCEAR 2008 which equal 0.32 mSv/y[99] .

Also, from same Table ,These results found FCR from all spices samples in the present study due to gamma emitters being within the world limit that equals2.5×10^{-3} [102,103].

4.4.2 Discussion the Results of Alpha Emitters

The average allowed globally of radon-222 gas in air (39 Bq/m^3) according to CRF [104], While, the allowed globally of other alpha emitters (radium-226 and uranium-238) were 30 Bq/kg for activity of radium-226 and 11.7 ppm for concentrations of uranium-238 according to UNSCEAR [30]. Therefore, it is noticed that from data in Tables (4-4), for C_a in all spices samples collected in the present study was within the world limit.

It is noticed from Table(4-4), as well as Figure (4-6) for specific activity of ^{226}Ra (C_{Ra}) all spices samples of the present study were within those proposed by UNSCEAR. Also, the results of uranium-238 in all samples of the present study were lower than acceptable of world levels.

From Table (4-5), The obtained results of total AAIED are lower than the worldwide average recommended by UNSCEAR which equal 1.2 mSv/y [105]. Also, the results values of RECFPMP in all spices samples of the present study were very little, so it may be neglected or located within the normal value.

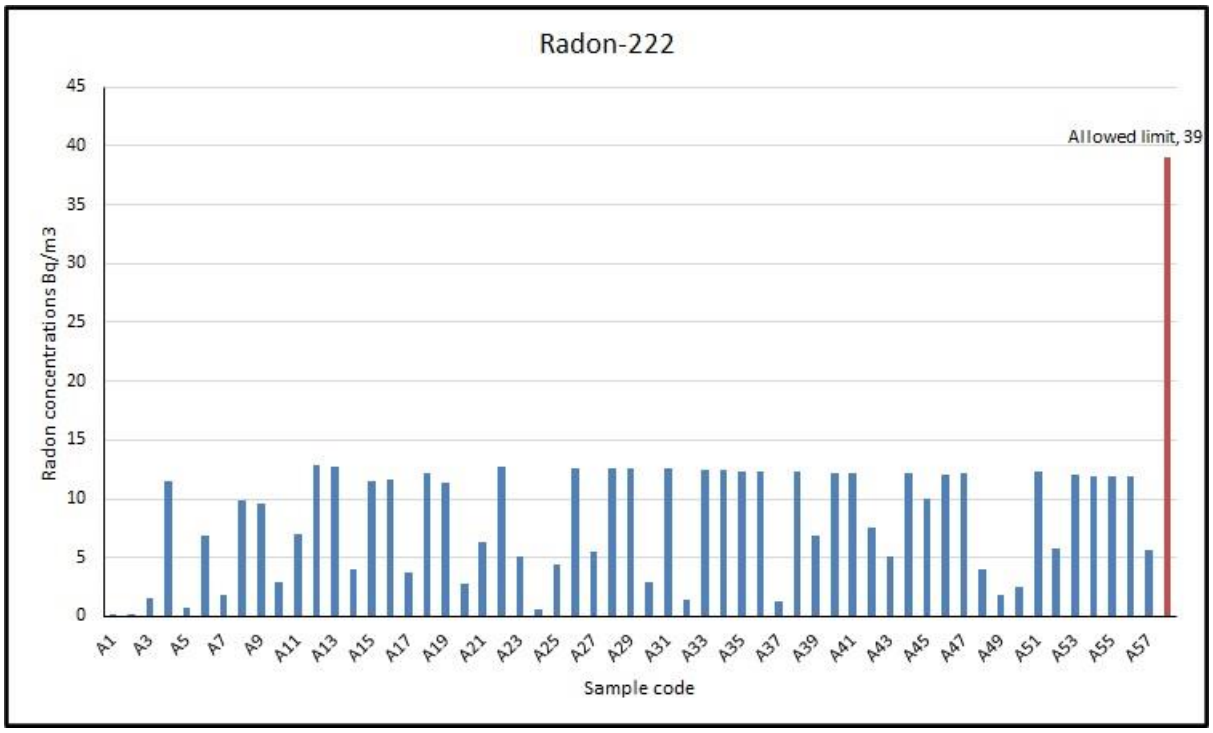

Figure (4-6): Comparing the results of ^{222}Rn in spices samples with global limit.

4.5 Compare the Results of the Present Study with previous studies

Table (4-6) compares the findings of specific activities of ^{238}U, ^{232}Th, ^{40}K, and ^{222}Rn in spice samples obtained from various locations in Iraqi markets with those of various other nations. As a result, Table (4-6) shows that the average of ^{238}U specific activity was higher than that of Sudan, Nigeria, Thailand, as well

as lower than that of Iraq and Ghana. Additionally, it was discovered that the ^{232}Th had higher average specific activity than Sudan, Ghana and Iraq, and lower average specific activity than Egypt, Ghana, and Nigeria, respectively. It was discovered that the average of ^{40}K specific activity was lower than Nigeria Ghana and Egypt. Greater than other nations are Sudan.

Table (4-6): Comparison of gamma emitters in the present study with other studies of many different countries

No.	Country	Average of specific activity in Bq/kg			Reference
		^{238}U	^{232}Th	^{40}K	
1	Sudan	0.82-5.27	0.03-9.65	19.25-2521.82	[9]
2	Egypt	----	18.7	578.8	[10]
3	Ghana	----	2.19	0.06	[12]
4	Iraq	----	0.16-0.67	18.7-220.4	[11]
5	Nigeria	2.19	46.73	729.85	[13]
6	Iraq	106.576	148.74	72.00	[14]
7	Ghana	31.8	56.2	839.8	[15]
8	Thailand	0.015-2.79	----	----	[16]
15	Iraq	12.052	8.760	256.924	Present study

Tables (4–7) compare the findings of Alpha emitters in spice samples taken from various Iraqi market locations with those taken from various other nations. Therefore, it can be shown from Table (4-7) that the average concentration of ^{222}Rn was lower than that of all countries, as was the average concentration of ^{226}Ra. According to Table, the average concentration of ^{238}U was found to be lower than that of other studies conducted in Iraq (4-7).

Table (4-7): Comparison of Alpha emitters in the present study with others studies of many different countries.

No.	Country	Concentrations Bq/m^3			Reference
		^{222}Rn	^{226}Ra	^{238}U	
1	Iraq	6.9621-1.5360	----	----	[17]
2	America	0.870.06	----	----	[18]
3	Iraq	26.5373.21	----	----	[19]
4	Nigeria	0.57-686.19	----	----	[20]
5	Iraq	126.47	0.943	9.322	[21]
6	Iraq	8.82	----	9.97-1.22	[22]
7	Iraq	0.258	0.0164	0.264	Present study

4.6 Compare results with different global limits of different foods.

Table (4-8) shows comparison of concentrations of uranium and thorium series radionuclides in foods and drinking water in some countries .Therefore, from Table (4-8), it is found the average concentration of ^{238}U in spices in the present study was larger than average concentration of ^{238}U in Milk products: in North America (United States), Asia(Japan) , Europe (Poland)(U.K) ,in Meat product: North America(United States), Asia (China), Europe(Germany, Romania, U.K),in Grain products: North America (United State), Asia(China),in Leafy vegetables ,all countries has concentration of ^{238}U larger than spices in present study ,in Root vegetables and fruits :North America(United States), Europe(Poland U.K). Fish products: Europe(U.K). Drinking water ,Asia(India), Europe (Poland, Spain) ,Also, concentration of ^{232}Th in spices in present study was larger than average concentration of ^{232}Th in Milk products : in North America (United States), Asia (China, India, Japan), Europe (Poland ,U.K.) ,Meat products: North America (United State), Asia (China

,Japan),Europe(Germany ,Romania, U.K.), in Grain products : North America (United State), Leafy vegetables :Europe(Germany, Poland, U.K),North America(United States), Asia(China, India, Japan),Europe(Germany, Poland ,Romania, U.K.) Root vegetables and fruits :North America (United State), Asia(China India, Japan),Europe(Germany, Poland, Romania, U.K), Fish products: North America (United States), Asia(China, Europe ,U.K.), Drinking water : North America (United State), Europe(France, Poland), as shown in Table (4-8).

Table (4-8): Concentrations of uranium and thorium series radionuclides in foods and drinking water.

Region / Country	Concentration (mBq kg^{-1})		Ref.
	^{238}U	^{232}Th	
Milk products			
North America United States	0.7	0.27	[106]
Asia China India Japan	 13 17 0.55	 1.2 0.29	[107]
Europe Poland U.K.	 2.6 0.1-4.9	 1.2	[108]
Meat products			
North America United States	0.8-2.3	0.3-2	[106]
Asia China Japan	 10 13	 4.3 2.3	[107]
Europe Germany Romania U.K.	 1-20 1.6-5.6 4.9	 0.5-3.6	[108]
Grain products			
North America United States	3-23	0.1-2.8	[106]
Asia			

China India Japan	9.8 7.4-67 1.2	13 1.2	[107]
Europe Germany Poland Romania U.K.	 20-400 4.7-11 6.1-85 6.2-35	 2.0-21 1.6-33 12	[108]
Leafy vegetables			
North America United States	 24	 18	[106]
Asia China India	 16 61-72	 23	[107]
Europe Germ Poland U.K.	 6-2 200 14-15 9.8-400	 4-7	[108]
Root vegetables and fruits			
North America United States	 0.9-7.7	 0.08-1.4	[106]
Asia China India Japan	 13 0.4-77 26	 4.7 2.3	[107]
Europe Germany Poland Romania U.K.	 10-2- 900 0.9-10 6-120 6	 0.7-7.1 0.4-2.1	[108]
Fish products			
North America United States	 13-1 900	 1.230	[106]
Asia China	 12	 1.3	[107]
Europe U.K.	 2.5		[108]
Drinking water			
North America United States	 0.3-77	 0.05	[106]
Asia China	 0.1-700	 0.04-12	[107]

India	0.09-1.5		
Europe Finland France Germany Italy Poland Romania Switzerland Spain	 0.5-150 000 4.4-930 0.4-600 0.5-130 7.3 0.4-37 0-1000 3.7-4.4	 0-4.2 0.06 0.04-9.3 	[108]
Iraq	12.052	8.760	Present study

4.7 Conclusions

1. Depending on the type of spice and the original, the samples of spices were found to possess natural gamma and alpha emitters at varying rates.

2. The information gathered in this study makes the NaI(Tl) and SSNTDs techniques more appropriate for such challenging samples.

3. All of the spice samples examined in this work have specific activity values for ^{238}U and ^{232}Th that are within the global range, according to UNSEAR 2008, while some samples have specific activity values for ^{40}K that are higher than the global range (Coriander origin of Syria) and (Chamomile origin of India) samples were only found to be higher than the worldwide average (420 Bq/kg),.

4. According to WHO, EPA, and ICRP, the results of alpha emitters such as ^{222}Rn, ^{226}Ra, and ^{238}U concentrations in all samples of spices in the current study were acceptable and within the permissible limit.

5. In most samples, the annual effective dose data from gamma and alpha emitters were below the accepted permissible limit.

6. It was discovered that all samples worldwide had values for internal hazard index and radium equivalent in accordance with UNSEAR 2000.

7. In all samples, the gamma and alpha emitters contribution to the cancer risk was below the accepted upper limit.

8.As aresult, the concentrations of ^{222}Rn, ^{226}Ra, and ^{238}U in the majority of spices samples tested in this paper, as well as the particular activity of ^{238}U, ^{232}Th, and ^{40}K, do not significantly alter the internal radiation dosage and are safe.

4.8 Recommendations

1. Educating people with health knowledge of food and the radioactivity of spices.

2. Tracking radioactivity in spices on the borders before its entrance into Iraq.

3. Carrying out regular studies for radioactivity in spices using high-tech detectors (HPGe) and other new techniologies.

4. Study of the radioactivity levels in other spices from different origins.

References:

1.Kennedy Jr, W.E. (2007)."Naturally occurring radioactive material (NORM V) proceedings of an international symposium", Spain19-22 March Oxford University Press.

2. Eisenbud, M. and T.F. Gesell. (1997). "Environmental radioactivity from natural, industrial and military sources: from natural, industrial and military sources".

3. Rosenberg, I.(2016)."Radiation oncology physics: a handbook for teachers and students". British journal of cancer, 98(5), 1020.

4. Annunziata, M.F., "Radioactivity introduction and history, from the quantum to quarks".

5. Hussain, M. and M. Rani.(2010).Quantitative measurement of natural radioactivity in vegetable and meat before and after cooking. Pakistan Journal of Agricultural Sciences, 47(2), 153-156.

6. Cunningham, S.D. and W.R. Berti.1993. Remediation of contaminated soils with green plants: an overview. In Vitro Cellular & Developmental Biology-Plant, 29(4),207-212.

7. " McGraw-Hill . (1987).encyclopedia of science and technology", 6th Ed., 19,75 -81.

8. Atlanta, GA, US. (1999).Agency for Toxic Substances and Disease Registry, ATSDR. Department of Health and Human services, public Health services.

9. HEF Hemada .(2009). Radioactivity levels of basic foodstuffs and dose estimates in Sudan. Academy of science, SAS Atomic Energy Council.

10.Nada Farhan Kadhim, Hyam Nazmy Badr, Hassan Ali Hassan, Mostafa Ya Mostafa.(2012).Determining the natural radioactivity of spices widely used in Iraq. international journal of Environmental Analytical Chemistry,1-12.

11. Rafat M Amin, and Fawzia Ahmed.(2013). Estimation of annual effective dose to the adult Egyptian population due to natural radioactive elements in ingestion of spices. Pelagia Research Library Advances in Applied Science Research, 4(5), 350-354.

12. C konsaana, EO Darko, OKAdukpo, Afaanu, E Shiti, Ns Opata, L Tettey-Larbi.(2013).mesurment of activity concentration of 226Ra,232Th,40KAnd 137Cs in some common spices consumed by in habitants in Accra Metropolis ,Ghana.int j food sci nutr Diet 2(8),75-80.

13. Lord ford tettey-Larby, E mmanuel Ofori Darko, Cyrils Schandorf , and Alfred Ampomah Appiah.(2013).Natural radioactivity levels of some medicinal plants commonly used in Ghana.springer plus 2(1),1-9.

14. CP Ononugbo, GO Avwiri, and SoIkhuiwu .(2017).Estimation of naturl radioactivity levels in some food spices commonly used in Nigeria and its radiological risks. Journal of Scientific Research and Reports, 16(3),1-9

15. AH Al-Mashhadani, RM Yas, WZ Majeed ,AA Saeed ,NB Naji, and W Abdul Hadi .(2020). Estimation the cancer risk due to ingestion the food spices commonly used in Iraqi kitchen. IOP Conference Series: Materials Science and Engineering.757(1),012014.

16. P Nochit, W Kulsawat, and J. Khunsamut. (2021).Concentrations of 238U in selected Thai spices and the related dose assessment. Journal of Physics Conference Series 1719(1),012077.

17.Nidhala H.K.Al-Ani, Nadaa Twafiq, Davser H chayb .(2010).Measurement of alpha emitters concentration in tomato fruits using CR-39 plastic track detector.Baghdad science journal .

18.L Oufni, N Manaut, S Taj, B Manaut. (2013). Determination of radon and thoron concentrations in different parts of some plants used in traditional medicine using nuclear track detectors. American journal of environmental protection. 1(2), 34-40.

19.Ali Abid Abo jassim, Heiyam Najy Hady, Abdul hussien Abdulameer Kareem.(2016).Radon levels in different types of plants with medicinal properties Madridge Journal of food technology1(1),18-21.

20. CP Ononugbo, and Go. Avwiri .(2018). Estimation of Lung Cancer Risk Due to Radon Exposure in Natural Food Spices. Archives of current Research international 12(3),1-10.

21.H N Alkhafaji, AA Abojassim,and AA Alkufi.(2019).Effective radium activity ,radon exhalation rate and uranium concentration in medical plants.Journalof physics .conference series 1234(1),012002.

22.Malik H kheder, Laith A Najam, Han N Azeez.(2020).-Long-lived alpha emitters concentration in the spices consumed in Iraq using CR-39detector – journal of university of Babylon for pure and Applied science, 28(1),274-283.

23.Safa Ahmed jabbar, fatin fadhel Mahmood, Inam H kadhim, Maha Madani. (2021).Detector to measure radon gas sample of spices use CR-39,journal of green engineering 11(2),1213-1219.

24. Hargreaves, T., & Moridi, R. (2010). X-Ray Safety Awareness Handbook for baggage X-Ray Machine Operators. Ottawa: Canadian air Transport Security Authority, 25-29

25. Radiation, E. P. A. (2012). Facts, Risks and Realities. Office of Air and Radiation.

26. Hashim, A. K., & Majeed, F. A. (2020). Alpha radioactivity emitted from Turkish edible oils used in Iraqi kitchen. International Journal of Nuclear Energy Science and Technology, 14(2), 133-140.

27. Ahmed, S. N. (2007). Physics and engineering of radiation detection. Academic Press

28. Outola, I., Nour, S., Kurosaki, H., Inn, K., La Rosa, J., Lucas, L., Koepenick, K. (2008). Investigation of radioactivity in selected drinking water samples from Maryland. Journal of Radioanalytical and Nuclear Chemistry, 277(1), 155-159.

29. Majeed, F. A., Kadhim, I. H., Muhsen, A. O., & Abass, K. H. (2015). Determination of alpha particles concentration in toothpaste using CR-39 track detector. Detection, 3(02), 9.

30. Siegbahn, K. (Ed.). (2012). Alpha-, beta-and gamma-ray spectroscopy. Elsevier

31. United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). Sources and effects of ionizing radiation, ANNEX B, Exposures from natural radiation sources. UNSCEAR 2000 REPORT, New York, 1, 97-99.

32.Cohen, B. L., & Cohen, I. B. L. (1971). Concepts of nuclear physics. McGraw-Hill Companies.

33. Kobashi, A. (1996). Radioactivity in books printed in Japan: Its source and relation to the year of issue. Journal of radiation research, 37(2), 81-95.

34. Evans, R. D. (1958). Compton effect. In Corpuscles and Radiation in Matter II/Korpuskeln und Strahlung in Materie II (pp. 218-298). Springer, Berlin, Heidelberg..

35. Shapiro, J. (2002). Radiation protection: a guide for scientists, regulators, and physicians. Harvard University Press..

36. Eisenbud, M., & Gesell, T. F. (1997). Environmental radioactivity from natural, industrial and military sources: from natural, industrial and military sources. Elsevier.

37. Da Conceicao, F.T. and D.M. Bonotto, "Radionuclides, heavy metals and fluorine incidence at Tapira phosphate rocks, Brazil, and their industrial (by) products". Environmental Pollution, 139(2): p.232 (2006)

38. Abojassim, A. A., Hashim, R. H., & Mahdi, N. S. (2021). Basics of nuclear radiation. Basics of Nuclear Radiation, 1-86.

39. Hashim, A. K., & Najam, L. A. (2015). Radium and uranium concentrations measurements in vegetables samples of Iraq. Detection, 3(04), 21. 40. De Grijs, R., An introduction to distance measurement in astronomy. 2011: John Wiley & Sons.

40. United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). Sources and effects of ionizing radiation, ANNEX B, Exposures from natural radiation sources. UNSCEAR 2000 REPORT, New York, 1, 97-99

41. Gilmore, G., Hemingway, J. D., & Durell, J. L. (1996). Practical gamma-ray spectroscopy. Journal of Physics G-Nuclear and Particle Physics, 22(7), 1117.

42. Lalit, B. Y., Shukla, V. K., & Ramachandran, T. V. (1981). Radioactivity content of books. Health physics, 40(5), 731-735. 43. Flores, O.B., et al., Natural radionuclide content in building materials and gamma dose rate in dwellings in Cuba. Journal of Environmental Radioactivity, 2008. 99(12): p. 1834-1837.

43.Je, I. (1997). Soil-gas radon-222 anomalies in south central Ontario, Canada (Doctoral dissertation).

44. United Nations Scientific Committee on the Effects of Atomic Radiation. (1993). Sources and Effects of Ionizing Radiation, Report to the General Assembly, with Scientific Annexes, Sources. UN, New York.

45. Camplin, G. Denis Henshaw"Tastraktm Plastic for the Detection of Radon and other Natural Alpha Radioactivity.

46. Hashim, A. K. (2003). A study of radon concentration in the soil and air of some villages in Irbid governorate (Doctoral dissertation, M. Sc. Thesis, Yarmouk University, Jordan).

47. Wilkening, M. (1990). Radon in the Environment. Elsevier.

48. Field, R. W. (1999). 14. Radon Occurrence and Health Risk. Occupational Medicine Secrets, 85.

49. Choppin, G. R., & Wong, P. J. (1998). The chemistry of actinide behavior in marine systems. Aquatic Geochemistry, 4(1), 77-101.

50. Hodgson, P. E., Gadioli, E., & Erba, E. G. (1997). Introductory Nuclear Physics, Clarendon.

51. Turner, J. E. (2007). Atoms, radiation and radiation protection. 3. comp. rev. and enl.

52.Weidner, R. T., & Sells, R. L. (1960). Elementary modern physics.

53. Blann, M. (1972). Importance of the nuclear density distribution on pre-equilibrium decay. Physical Review Letters, 28(12), 757. 53. Roedler, H.D., A. Kaul, and G.J. Hine, Internal radiation dose in diagnostic nuclear medicine. 1978.

54. Hashim, A. K., Najam, L. A., & Al-Alawy, R. (2015). Effective radium content and radon flux determination in cereals and legumes Iraqian products. Atti della "Fondazione Giorgio Ronchi, 70, 6.

55. Gaso, M. I., Segovia, N., Cervantes, M. L., Herrera, T., Perez-Silva, E., & Acosta, E. (2000). Internal radiation dose from 137Cs due to the consumption of mushrooms from a Mexican temperate mixed forest. Radiation Protection Dosimetry, 87(3), 213-216.

56. Roedler, H. D., Kaul, A., & Hine, G. J. (1978). Internal radiation dose in diagnostic nuclear medicine.

57.Hashim, A. K., Najam, L. A., & Tettey-Larbi, L. (2015). A study of radon concentration in different brands tobacco cigarette in Iraqi market, influencing factors and lung cancer risk. International Journal of Science and Technology, 5(10). 115

58. Hotte, E. D., Krueger, D. J., & Connor, K. (2000). Radiation safety. Handbook for laboratory workers in the USA.

59.Hashim, A. K., Hameed, A. S., Mohammed, E. J., & Fuliful, F. K. (2019). Measurement of alpha particle concentrations in different chips samples from Iraqi market. In AIP Conference Proceedings (Vol. 2144, No. 1, p. 030017). AIP Publishing LLC.

60. Samavat, H., Seaward, M. R. D., Aghamiri, S. M. R., & Reza-Nejad, F. (2006). Radionuclide concentrations in the diet of residents in a high level natural radiation area in Iran. Radiation and environmental biophysics, 45(4), 301-306. 61.

62. Mostofizadeh, A., X. Sun, and M. Kardan. (2008). Improvement of nuclear track density measurements using image processing techniques. American Journal of Applied Sciences, 5(2), 71-76.

63. Ashry, A.(2014).The use of CH3OH additive to NaOH for etching alpha particle tracks in a CR-39 plastic nuclear track detector. Radiation Physics and Chemistry, 101, 41-45.

64. Eappen, K. and Y. Mayya.(2009). Factors affecting the registration and counting of alpha tracks in solid state nuclear track detectors. Indian Journal of Physics, 83(6),751-757.

65. Al-Ubaidi, K. H. (2006). Identification and measurements of natural and industrial radioactive pollutants in environment of Baghdad city using gamma spectrometry and solid state nuclear track detector CR-39. Ibn Al-Haitham Baghdad University. 117

66.Oda, K., Csige, I., Henke, R. P., & Benton, E. V. (1992). A new method for internal calibration of nuclear track detectors. International Journal of Radiation Applications and Instrumentation. Part D. Nuclear Tracks and Radiation Measurements, 20(3), 505-510.

67.Knoll, G. F. (2010). Radiation detection and measurement. John Wiley & Sons.

68. Mostofizadeh, A., Sun, X., & Kardan, M. R. (2008). Improvement of nuclear track density measurements using image processing techniques. American Journal of Applied Sciences, 5(2), 71-76.

69. Ashry, A. H., Abdalla, A. M., Rammah, Y. S., Eisa, M., & Ashraf, O. (2014). The use of CH3OH additive to NaOH for etching alpha particle tracks in a CR-39 plastic nuclear track detector. Radiation Physics and Chemistry, 101, 41-45.

70. Eappen, K. P., & Mayya, Y. S. (2009). Factors affecting the registration and counting of alpha tracks in solid state nuclear track detectors. Indian Journal of Physics, 83(6), 751-757.

71. Durani, S. A., & Ilic, R. (1997). Radon measurements by etched track detectors: application in radiation protection, earth science and the environment. Word Scientific 70. Mohammad, A.I. and N.N. Al-Zubaidy, Estimation of natural radioactivity in water and soil in some villages of irbid city. Applied physics research, 2012. 4(3): p. 39.

72. Erdi-Krausz, G., Matolin, M., Minty, B., Nicolet, J. P., Reford, W. S., & Schetselaar, E. M. (2003). Guidelines for radioelement mapping using gamma ray spectrometry data: also as open access e-book. International Atomic Energy Agency (IAEA).

73.L'Annunziata, M. F. (2012). Handbook of Radioactivity Analysis, Academic press. Waltham, USA. 119

74. Okogbue, C., & Nweke, M. (2018). The 226Ra, 232Th and 40K contents in the Abakaliki baked shale construction materials and their potential radiological risk to public health, southeastern Nigeria. J Environ Geol Vol, 2(1), 14.

75. UNSCotEoA, R. (2000). Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR (Vienna, Austria).

76. Moszyński, M., Zalipska, J., Balcerzyk, M., Kapusta, M., Mengesha, W., & Valentine, J. D. (2002). Intrinsic energy resolution of NaI (Tl). Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 484(1-3), 259-269.

77. Mohammad, A. I., & Al-Zubaidy, N. N. (2012). Estimation of natural radioactivity in water and soil in some villages of irbid city. Applied physics research, 4(3), 39.

78.Stannard, J. N., & Baalman Jr, R. W. (1988). Radioactivity and health: A history

79. Ibrahim, A. A., Hashim, A. K., & Abojasim, A. A. (2020). The Impact of Long-Lived Gamma Emitters on Human Health in Selected Soil Samples at Karbala University-Fariha Site. Prensa Med Argent, 106, 5.

80. Al-Saadi, A. J., Hashim, A. K., & Hussein, F. M. (2013). Measurement of radon and uranium concentrations in the dates and their seeds of different regions in Karbala governorate. Journal of Babylon University/Pure and Applied Sciences, 21(6), 2134-2147.

81. Qasim, A. M. S., Hussain, H. H., & Abojassim, A. A. (2018). Radon concentrations and annual effective dose in cigarette samples (domestic and imported) at the Iraqi markets. Journal of Radiation and Nuclear Applications, 3(2), 83.

82. Abojassim, A. A., & Rasheed, L. H. (2021). Natural radioactivity of soil in the Baghdad governorate. Environmental Earth Sciences, 80(1), 1-13.

83. Abojassim, A. A. (2017). Annual effective dose of gamma emitters in infants, children and adults for frozen chicken samples consumed in Iraq. Curr Pediatr Res, 21(3), 520-525. 120

84. Aswood, M. S., Abojassim, A. A., & Al Musawi, M. S. A. (2019). Natural radioactivity measurements of frozen red meat samples consumed in Iraq. Radiation Detection Technology and Methods, 3(4), 1-4.

85.DHAHIR, D. M., ALI, A. S., & ABOJASSIM, A. A. (2019). Natural Radioactivity in Custard Samples of Iraqi Market from Different International Sources. Annals of Agri-Bio Research, 24(2), 372-376.

86. United Nations Scientific Committee on the Effects of Atomic Radiation. (2008). Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2006 Report, Volume I: Report to the General Assembly, Scientific Annexes A and B. United Nations.

87. Kolapo, A. A., & Omoboyede, J. O. (2018). Health risk assessment of natural radionuclide and heavy metals in commonly consumed medicinal plants in south-west Nigeria. Ife Journal of Science, 20(3), 529-537.

88. Abojassim, A. A., & Mohammed, H. A. U. (2017). Comparing of the uranium concentration in tap water samples at Al-Manathera and Al-Herra Regions of Al-Najaf, Iraq. Karbala International Journal of Modern Science, 3(3), 111-118.

89. Fleischer, R. L., & Mogro-Campero, A. (1978). Mapping of integrated radon emanation for detection of long-distance migration of gases within the Earth: Techniques and principles. Journal of Geophysical Research: Solid Earth, 83(B7), 3539-3549.

90. Elzain, A. E. A. (2014). Measurement of Radon-222 concentration levels in water samples in Sudan. Advances in Applied Science Research, 5(2), 229-234.

91. Azam, A., Naqvi, A. H., & Srivastava, D. S. (1995). Radium concentration and radon exhalation measurements using LR-115 type II plastic track detectors. Nuclear geophysics, 9(6), 653-657.

92. Podgorsak, E. B. (2005). Basic radiation physics. Radiation oncology physics: a handbook for teachers and students. Vienna: IAEA, 7.

93. Wong, S. S. (2008). Introductory nuclear physics. John Wiley & Sons.

94.Al-Omari, S. (2015). Radioactivity measurement of 222Rn, 226Ra and 238U in pharmaceuticals and evaluation of cancer risk. International Journal of Low Radiation, 10(1), 61-73.

95. National Research Council. (1999). Risk assessment of radon in drinking water. 122

96. Najam, L. A., Mohammed, E. J., & Hameed, A. S. (2019). Estimation of radon exhalation rate, radium activity and uranium concentration in biscuit samples in Iraq. Iranian Journal of Medical Physics, 16(2), 152-157.

97. Abid, A. A., Mraity Hussien, A. A., Husain, A. A., & Wood, M. (2017). Estimation of the excess lifetime cancer risk from radon exposure in some buildings of Kufa Technical Institute, Iraq. Nuclear physics and atomic energy, 18 (3), 276-286.

98. Clarke, R. H., & Bines, W. (2011). Evolution of ICRP recommendations-1977, 1990, and 2007. Changes in underlying science and protection policy and case study of their impact on European and UK Domestic Regulation 2011.

99. United Nations Scientific Committee on the Effects of Atomic Radiation. (2008). Ionizing radiation: Sources effects and risks of ionizing radiation. Report to the General Assembly. New York: United Nations.

100. Agency, N.E., (1979). "Exposure to radiation from the natural radioactivity in building materials: report". OECD.

101. Rosenberg, I. (2008). "Radiation oncology physics: a handbook for teachers and students". British journal of cancer, 98(5): p. 1020.(2008).

102. Idriss, H., & Elhassan, H. M. (2020). Preliminary survey of ^{226}Ra, ^{232}Th and ^{40}K activity level and their cancer risk in some foodstuff, Sudan. British Food Journa, 107, 2411-2502.

103. International Commission on Radiological Protection (ICRP), 1991.1990 Recommendation of International Commission of Radiological protection. Pergamon Press, Oxfored, UK, ICRP Publication 60.

104. CFR, U. (2009). Code of Federal Regulations Title 40: Protection of Environment, Part 136–Guidelines establishing test procedures for the analyses of pollutants, Appendix B to Part 136–definition and procedure for the determination of Method Detection Limit rev. 1.11.

105. United Nations Scientific Committee on the Effects of Atomic Radiation. (1988). Sources, effects and risks of ionizing radiation

106. Fisenne, I.M., P.M. Perry, K.M. Decker . (1987). The dailyintake of $^{234, 235, 238}$U, $^{228, 230, 232}$Th and $^{226, 228}$Ra by NewYork City residents. Health Phys. 53(4): 357-363.

107. Zhu, H., S. Wang, M. Wei . (1993). Determinations ^{90}Sr,^{137}Cs, ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{210}Po contents in Chinese diet and estimations of internal doses due to these radionuclides Radiation. Prot. 13: 85-92.

108. Pietrzak-Flis, Z., M.M. Suplinska and L. Rosiak. (1997). The dietary intake of ^{238}U, ^{234}U, ^{230}Th, ^{232}Th, ^{228}Th and ^{226}Ra from food and drinking water by inhabitants of the Walbrzych region. J. Radioanal. Nucl. Chem. 222(1-2):189-193.

الخلاصة:

التوابل (البهارات) هي أحد المكونات الرئيسية التي يشيع استخدامها في جميع المطابخ العراقية وهي عبارة عن منتجات نباتات استوائية وربما لحاء أو جذور أو براعم أو فاكهة أو أجزاء أخرى. يمكن احتوائه في تراكيز بعض نويدات النشاط الإشعاعي التي تنتجها سلسلة نووية ، مثل سلسلة اليورانيوم^{232}U والثوريوم ^{232}Th بالإضافة إلى نظير البوتاسيوم ^{40}K تعتبر معرفة مستويات النشاط الإشعاعي في النظام الغذائي البشري مصدر قلق خاص لتقدير المخاطر الإشعاعية المحتملة على صحة الإنسان.

لذلك ، تم جمع 57 عينة توابل من مواقع مختلفة من الأسواق العراقية لقياس النويدات المشعة الطبيعية. بواعث أشعة كاما (^{232}U ، ^{232}Th ،و ^{40}K)وبواعث ألفا (^{222}Rn، ^{226}Ra، و ^{238}U)مقاسة بواسطة مطيافية أشعة كاما وكاشف المسار النووي للحالة الصلبة ، على التوالي. بالإضافة إلى تحديد المخاطر الإشعاعية بسبب بواعث كاما وألفا للعينات.

تظهر نتائج بواعث كاما: أن متوسط قيم النشاط الاشعاعي المحدد U- 238 (12.052±1.247Bq/kg) وTh-232 (8.760±0.650 Bq/kg)،وK-40كانت(256.924±5.966Bq/kg),في حين أن الحد العالمي وفقًا لـ UNSCEAR لـ (238 -Uو 232 -Th و 40 -K)هو (33Bq / kgو 45Bq / kg و 420 Bq / kg)، فقد وجد أن جميع قيم 238 -Uو 232 -Thللأنشطة المحددة كانت أقل من الحدود العالمية المسموح بها. في حين أن جميع قيم النشاط المحدد للبوتاسيوم 40 -Kأقل من قيمة المتوسط العالمي ، باستثناء عينات (الكزبرة سورية المنشأ والبابونج هندي المنشأ) فقط وُجدت أعلى من المتوسط العالمي (420 Bq / kg)، وأيضًا نتيجة نشاط مكافئ الراديوم (Ra_{eq}) ومؤشر المخاطر الداخلية (H_{in}) (44.315،0.152)على التوالي ، ومتوسط قيمة إجمالي الجرعة الفعالة السنوية (AED) بسبب بواعث كاما هو 0.0128 mSv/y ، ومتوسط قيمة معدل استهلاك العتبة (DI_{thresh}) هو 53.917kg/y ، متوسط مخاطر الإصابة بالسرطان الوراثي (HCR) هو 0.0351×10^{-3} ، ومتوسط قيمة مخاطر السرطان القاتلة (FCR) هو0.439×10^{-3}، وكل هذه القيم لانبعاثات كاما أقل من المتوسط العالمي.

أظهرت نتائج باعثات ألفا: ان متوسط تركيز الرادون (C_{Rn}) هو 0.258Bq/kg ، ومتوسط تركيز الراديوم C_{Ra} هو 0.0164mBq/kg ، ومتوسط تركيز اليورانيوم (C_U) هو0.264Bq/kg ، ومتوسط الجرعة الداخلية السنوية(AAIED)هو 0.0300 µSv/y ، ومتوسط خطر الإصابة بالسرطان لكل مليون شخص (RECFPMP) هو 0.0097 كل هذه القيم أقل من المتوسط العالمي. أخيرًا ، أن مستويات النشاط الإشعاعي الطبيعي (بواعث كاما وألفا) جنبًا إلى جنب مع المخاطر الإشعاعية من خلال المقارنة مع الحدود العالمية المسموح بها ، وكذلك المقارنة مع الدراسات المحلية والدولية السابقة ، وجد أن ال 57 عينة من التوابل التي تم دراستها لا تسبب أي خطر على صحة الإنسان عند تناولها.

جامعة كربلاء

كلية العلوم

قسم الفيزياء

تقييم المخاطر الإشعاعية للنويدات المشعة في عينات مختلفة من التوابل في الأسواق العراقية

رسالة مقدمة الى مجلس كلية العلوم / جامعة كربلاء

كجزء من متطلبات نيل درجة الماجستير في علوم الفيزياء

من قبل

آلاء سعد عبيد

بإشراف

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1444 هـ 2022م