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Determination of Uranium and Radon Concentrations in Selected Blood Samples of Karbala Governorate

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 Science Physics

by

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بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

هُوَ الَّذِي بَعَثَ فِي الْأُمِّيِّينَ رَسُولًا مِّنْهُمْ يَتْلُو عَلَيْهِمْ آيَاتِهِ وَيُزَكِّيهِمْ وَيُعَلِّمُهُمُ الْكِتَابَ وَالْحِكْمَةَ وَإِن كَانُوا مِن قَبْلُ لَفِي ضَلَالٍ مُّبِينٍ

"صدق الله العليّ العظيم"

سورة الجمعة - الآية ٢

Certificate

We certify that the preparation of this thesis, entitled "**Determination of Uranium and Radon Concentrations in Selected Blood Samples of Karbala Governorate**" was made under our supervision by (Zainab Ali Rasheed) at the Department of physics, College of the Science, University of Karbala in partial fulfillment of the requirements for the degree of Master of Science in Physics.

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Dedication

- To my father and mother.....Without them, I would not exist in this life, and from them, I learned steadfastness and love of life, no matter the difficulties.

- To my honorable professors....., from them I learned letters, learned how to pronounce words, formulate phrases, and resort to rules in the field.

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- To my dear friend Fatima.

Dedicate to you my humble work

Zainab

Abstract

In this study, the concentration of Uranium and Radon was measured in blood samples of cancer patients (Leukemia, Digestive System, and Kidney) using the solid-state nuclear to track detector CR-39, with a thickness of 500 μm and an area (1×1) cm^2. A total of 115 samples of different ages were collected for examination, including 75 samples from cancer patients and 40 samples from the healthy group. Samples were taken from Al-Hussein Medical City Hospital in Karbala Governorate. The concentration of uranium was measured in 30 samples of children, 25 patients with Leukemia and 5 from the healthy group, where the highest rate of Uranium concentration in the group of pediatric Leukemia patients was 0.874 ppb compared to the healthy group at 0.279 ppb. The other part of the study included measuring Uranium concentration in 60 samples, which are 50 patients with cancer in the Digestive System and Kidneys, and 10 in the healthy group, where the highest rate of uranium concentration in the group of cancer patients at 0.8812.ppb and the control group 0.381ppb. As a result of these concentrations, we say that there is a relationship between Uranium concentration, gender and age The highest concentration of uranium in the group of pediatric Leukemia patients was 1.874 ppb compared to the healthy group at 0.33 ppb The average concentration of Uranium for the group of healthy and patients was 0.279 ppb and 0.874 ppb, respectively, and included The other part of the study measured the concentration of uranium in 60 samples, 50 cancer patients with (Digestive System, and Kidney) and 10 in the healthy group, where the highest concentration of Uranium was in the cancer patients group. It is at 2.164 ppb and the healthy group is 0.614 ppb. The average concentration of Uranium for the healthy group and patients was 0.335 ppb and 0.8812 ppb, respectively. As a result of these concentrations, we found a relationship between Uranium concentration, gender and age, and we also found the percentage of Uranium concentration in females is higher

than in males, where the concentration of Uranium increases in females and males with age the patient.

Radon concentration was measured in 80 blood samples, including 50 samples from cancer patients and 30 samples from healthy controls. After collection, the samples were stored for 60 days in tubes. We used the CR-39 nuclear track detector (2.5 x 2.5) cm^2 to measure the trajectory of the alpha particles. The average Radon concentration in the samples of cancer patients was calculated, which Ranged between (5.832-0.348) Bqm^{-3}, as well as the ratio of Radon concentration in the healthy group, and ranged between (2.142-0.244) Bqm^{-3}. We also found that the concentration of Radon gas in males is relatively higher than in females, due to the fact that the percentage of pollution to which males are exposed is higher than that of females.

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LIST OF SYMBOLS AND A CRONYMS

θ_c	Critical Angle
β^-	Negative Beta Particles
β^+	Positive Beta Particles
ω_{NaOH}	Molecular Weight of NaOH
A	Mass Number
ALL	Acute lymphoblastic leukemia
ARS	Radiation Syndrome
A_U	Viewing Area of the Optical Microscope
Bq	Becquerel
CE	Chemical Etching
Ci	Curie
cm	Centimeter
C_{ST}	Uranium Concentration for Standard Samples
C_U	Uranium Concentration of Unknown Samples
d	Day
D	Engraved Track
d	Diameter of the Track
DNA	Deoxyribo Nucleic Acid
E	Energy
EDTA	Ethylene Demine Tetra Acetic Acid
FMMP	Fernald Medical Monitoring Program
FTA	Fission Track Analysis
gm	Grams
Gy	Gray
ICRP	International Commission on Radiological Protection.
keV	Kilo Electron Volts
Km	Kilometer
L	Depth
LD	Lethal Dose
l_o	Represents the Length of the Visible Tracks of the Detector
MeV	Million electron volts
ml	Milliliters
mm	Millimeter
n	Neutron
N	Normality
N_U	Number of Tracks of Uranium Samples
^oC	Celsius
p	Significant Value
PADC	Polyallyl Diglycol Carbonate
PMNs	Polymorphonuclear leukocytes
ppb	Parts Per Billion
ppm	Parts Per Million

P_{ST}	Density of Tracks for the Standard Samples
P_U	Density of Tracks for the Unknown Samples
Rad	Radiation Absorbed Dose
S	Second
S.D	Standard Deviation
SSNTD	Solid State Nuclear Track Detector
Sv	Sievert
T	Time
$t_{1/2}$	Half-life
U.Con.	Concentration of Uranium
v	Speed
V	Etching Rate Ratio
V_P	Average Speed of Track Etching of the Bulk Material
V_T	Average Speed of Track Etching of the Damaged Material
V_W	Volume of the Solution Used to Dissolve NaOH
WHO	World Health Organization
W_{NaOH}	NaOH Weight
y	Year
Z	Atomic Number
α	Alpha
γ	Gamma
Δ	Half the Angle of the Cone
θ	Zenith Angle
µgm	micrograms
ω	Etching Efficiency
β	Beta
$\varkappa$	Solution Concentration
ϕ	Azimuth Angle

CHAPTER ONE
GENERAL INTRODUCTION

1. Introduction

The oldest nuclear radioactivity is produced in stars. Through which radioactive and stable isotopes were formed. The initial formation of the planet showed that the age of the earth is about $4.5x10^9$ years, despite the long life of the Earth, there are nuclides with long half-lives [1]. Usually, in nature, there are continuous processes that lead to the production of new radioactive isotopes, and human activities have also contributed to the increase of some radionuclides, and this has led to an impact on human activity. The increase in radioactive pollution is due to the development of technology, especially nuclear fusion, as well as nuclear radiation, radiation in medicine, the generation of nuclear energy, and natural sunlight [1]. The radiation of charged particles coming from the sun and stars interacts with the magnetic field and the Earth's atmosphere, producing a continuous stream of ionizing radiation (such as beta and gamma rays). Radioactive isotopes from natural (terrestrial) sources are present in our bodies since birth, and natural radioactivity is added to our bodies every day through breathing air, eating food, drinking water, and others. So all humans contain radiation (radioactive) [2]. Determining the acceptable tourist and residential areas for living by measuring the radioactivity of the area, which must be taken into account to reduce the impact of radiation on human life [1].

1.2 Types of Radiation

1.2.1 Non-ionizing Radiation

It is the radiation that does not have enough energy to ionize, such as ultraviolet rays, radio frequency radiation, and others [2].

1.2.2 Ionizing Radiation

It is the energy that ejects electrons from atoms and is in the form of waves or particles, and it is one of the important things for the composition of the

universe. The heat and light of stars are caused by nuclear fusions that occur in them, which lead to ionizing radiation such as neutrons and γ rays.

The nuclear synthesis related to the radiation inside the stars led to the production of supporting life (Hydrogen, Oxygen, Nitrogen, and other elements in the human body). Therefore, life on Earth is due to one of its causes, which is the previous nuclear reactions.

There are two types of ionizing radiation particles and electromagnetism, as particles include α and βparticles (β^- : negative beta particles, β^+: positive beta particles), and heavy ions, while ionizing electromagnetic radiation include γ rays and X-rays.

- **Alpha (**α) particles are heavy, positively charged particles. α particles can be stopped through a sheet of paper or the surface layer of our skin (epidermis). However, alpha emissions can stray into the internal organs of the human body and cause damage to them [1].
- **Beta (**β) particles are more penetrating than α particles, as they can penetrate (1-2) cm of water [1].
- **Gamma (**γ) **rays** are electromagnetic rays similar to X-rays. It can pass through the human body because of its high energy. The X-rays can be attenuated [1].
- **Neutrons** are uncharged particles that do not produce any ionization directly when interacting with matter, but when neutrons interact with matter, they produce alpha, beta, and gamma or X-rays, which then ionize through. Neutrons can be stopped by slabs of concrete, water, or paraffin.

  Two main quantities determine the levels of radiation and its effects, the radioactivity of the radioactive substance and the radiation dose.

- **The activity of a radioactive** substance is the number of nuclear dissociations per unit time and unit Becquerel (Bq) [1].

One Becquerel is one disintegration per second.

- **As for radiation dose**, it means several concepts such as (absorbed dose, equivalent dose, or effective equivalent dose) [1].

The absorbed dose is a basic quantitative amount representing the energy transferred to a substance per unit mass by radioactive ionization. The unit of measurement for the absorbed energy is the rad or gray in the SI unit [3].

An equivalent dose or effective equivalent dose is a quantity that expresses the effect of radiation and genetic effects resulting from types of ionizing radiation. It is derived from the absorbed dose, but it takes the biological activity of the ray and is measured in the rem unit, and the SI equivalent unit is the Sievert [3].

It has not yet been proven that natural radiation that affects the human body causes harm. The age of 2years, a person has received more than 60 trillion natural radiation strikes that are not harmful to the body. By the age of 20years, the number of non-ionizing radiation strikes has exceeded 630 trillion. Electromagnetic radiation that has insufficient energy to ionize is called non-ionizing radiation [2].

1.3 Decay Chains

In nuclear sciences, decay chains refer to a series of radioactive decays of different radioactive elements, known as a (radioactive cascade). Most radioactive isotopes do not decay directly to a stable state but undergo a series of decays until they eventually reach a stable isotope [4].

There are three main chains in nature, and these chains are the Thorium (^{232}Th) series, the Uranium (^{238}U) series, and the Actinium (^{235}U) series, as they end with three different and stable isotopes of Lead (Pb) as shown in the table (1.1). Where the mass number of each isotope can be represented in the chains of

(A = 4Ń, A = 4Ń +2, A =4Ń +3), ^{232}Th, ^{238}U, and ^{235}U respectively, and since the formation of the earth, ignoring the decay of industrial elements since 1940 years.

There is a fourth series, which is the Neptunium (^{237}Np) series (A = 4Ń +1), but due to its short half-life of 2.14 million years, this series has already naturally become extinct.[5] Where if we denote the mass number A in the form (A = 4Ń + M) (where Ń is a natural number between 51 to 59, and M is one of the numbers from 0 to 3) [6].

Table 1-1:The decay of radioactive chains [7]

series	first element	half.life(y)	last element(stable)
Thorium	^{232}Th	$1.39x10^{10}$	^{208}Pb
Uranium	^{238}U	$4.5x10^{9}$	^{206}Pb
Actinium	^{235}U	$7.10x10^{8}$	^{207}Pb
Neptunium	^{237}Np	$2.14x10^{9}$	^{209}Bi

1.3.1 Thorium^{232}Th Series

It is a (4Ń) series, and this series includes the following elements: Actinium, Bismuth, Lead, Polonium, Radium, Radon, and Thallium. Thallium and these elements are naturally found in every sample that contains natural Bismuth, whether it is a compound or a metal, and this series ends with ^{208}Pb. The total energy from Thorium to lead is 42.6 MeV. As shown in figure (1.1) [4].

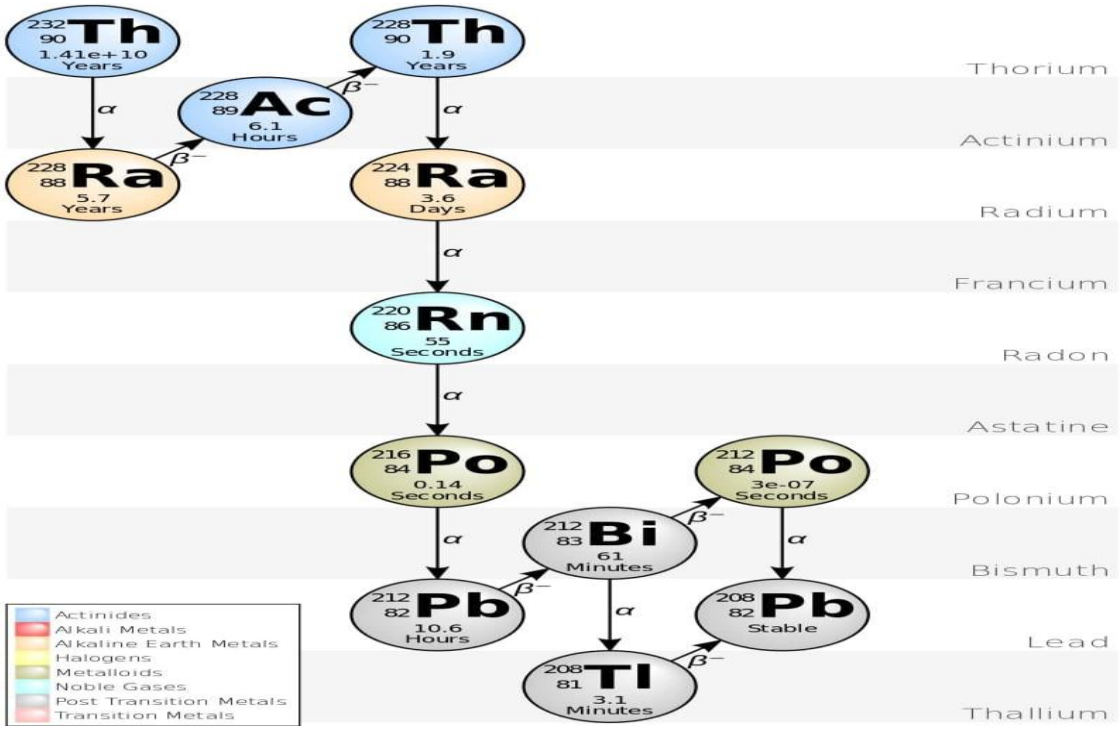

Figure (1.1): Thorium(^{232}Th) decay chain[4]

1.3.2 Neptunium ^{237}Np Series

A series (A = 4Ń +1) with a half-life of 2.2 x10^{6}y, which is much less than the age of the Earth. Approximately during the first 50 million years, all the Neptunium(^{237}Np) decayed after the formation of the Earth[8]. As this series differs from the other three, it ends with Thallium instead of Lead, as this series differs from the other three ending with Thallium instead of Lead, The total energy released from Californium-249 to Thallium-205, including the energy lost to neutrinos, is 66.8 MeV. As shown in figure (1.2) [4].

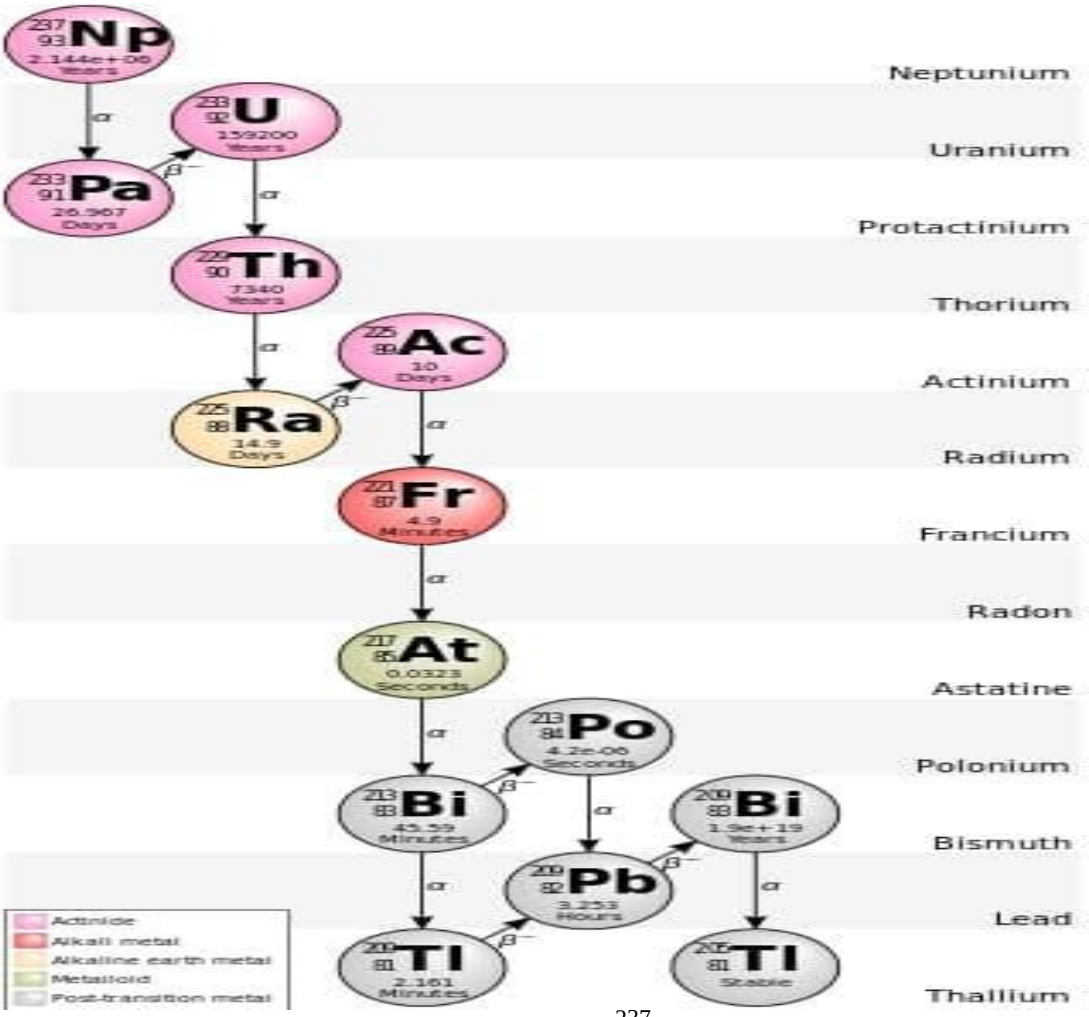

Figure (1.2): Neptunium(^{237}Np) decay chain[4]

1.3.3 Uranium ^{238}U Series

A series starting from naturally available Uranium (^{238}U), in clouding Astatine, Bismuth, Lead, Polonium, Protactinium, Radium, Mercury, Radon, Thallium, and Thorium. All are available in any sample containing natural Uranium. It ends with ^{206}Pb, and the total energy of the decay formed is 51.7 MeV, as shown in figure (1.3) [4].

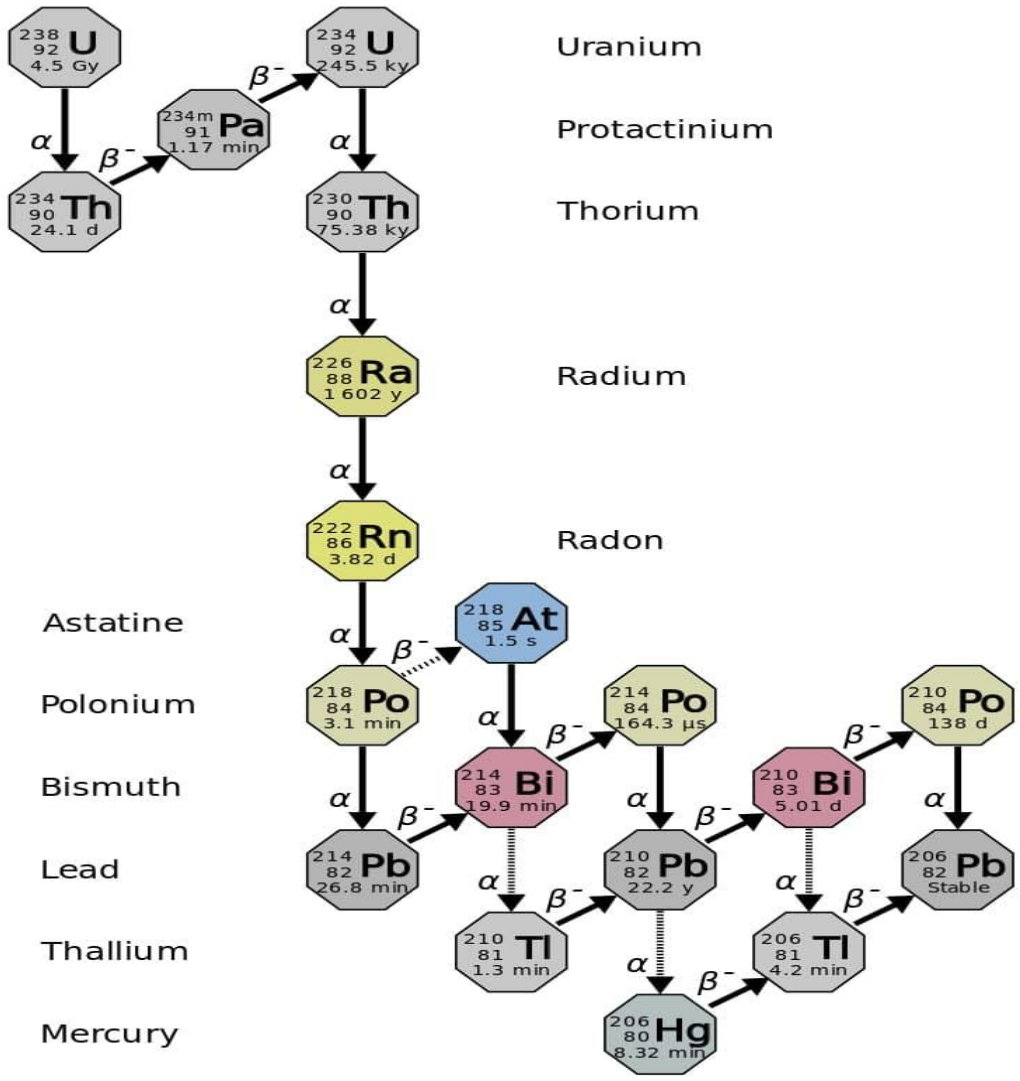

Figure (1.3): Uranium (^{238}U) decay chain[4]

1.3.4 Actinium ^{235}U Series

The (4N+3) series starts from the radioactive isotope Uranium ^{235}U and consists of the following elements (Actinium, Astatine, Bismuth, Francium, Lead, Polonium, Protactinium, Radium, Radon, Thallium, and Thorium. All are present, at least transiently, in any sample containing ^{235}U and end with ^{207}Pb. The total energy released from its dissolution is 46.4 MeV as in figure (1.4)[4].

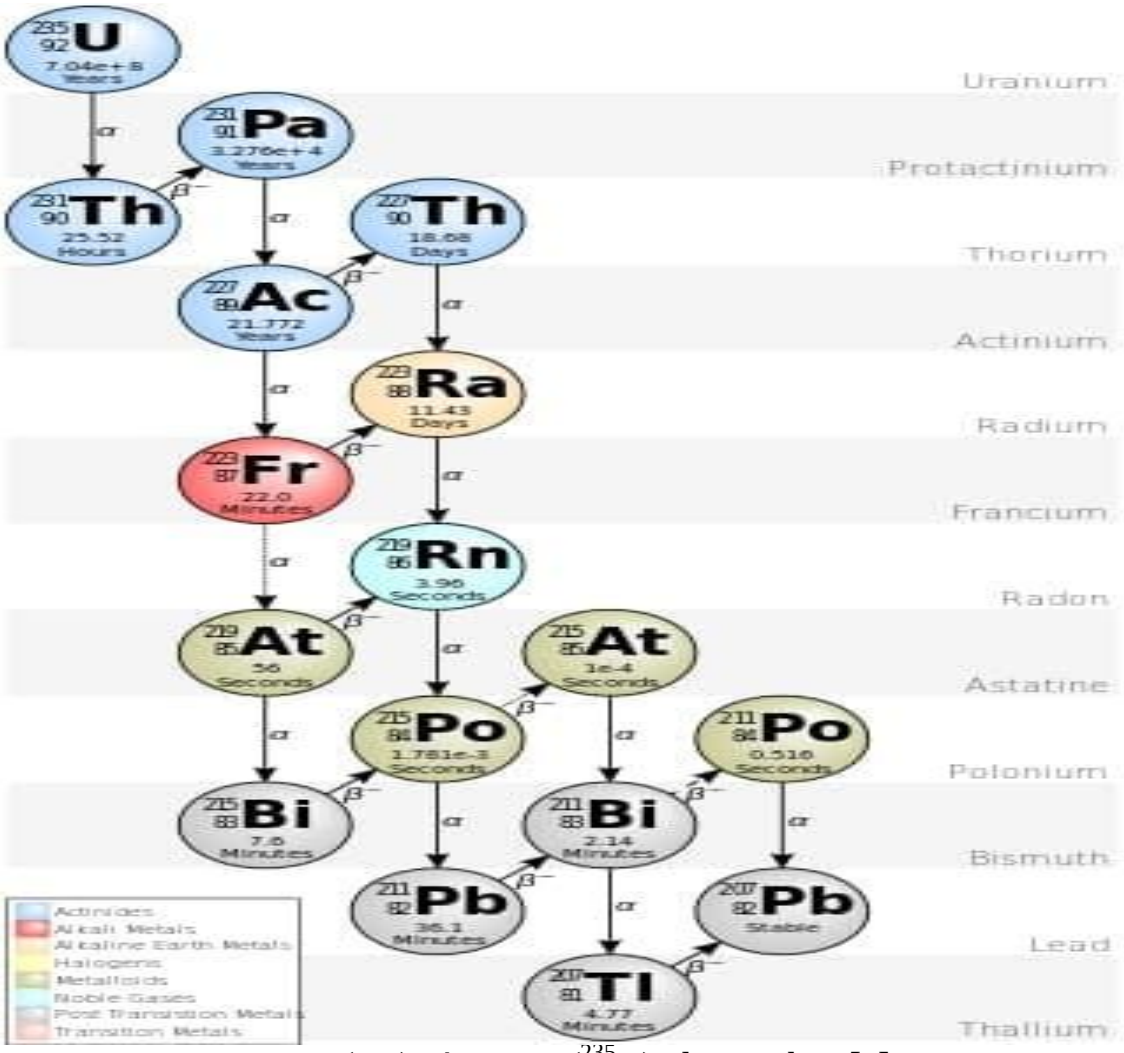

Figure (1.4): Actinium(^{235}U) decay chain[4]

1.4 Radon Gas

Radon is a radioactive and chemically inert natural gas. It was discovered by the German physicist Friedrich Ernst Dron in the year (1900) naturally produced from the dissolution of natural elements in our environment Uranium and Thorium where it cannot be detected through its chemical properties (it does not react chemically with most materials), colorless, odorless, invisible and without a taste that cannot be known (discovered) through the human senses[9]. Until recently, no more than four decades ago, it was believed that it is safe and beneficial. But turns out that it and its isotopes constitute about half of the

effective radiation dose to which the general public is exposed from all radioactive confiscation. The series of ^{222}Rn decay is illustrated in figure (1.5) with the source. Radon moves easily through small distances in rocks and soil, where it can move to the surface of the soil and move to the air. As for Uranium, it remains underground and merges with the groundwater[10], scientifically known as radon as ^{222}Rn because of the most abundant isotopes of Radon[11],[12]. ^{219}Rn is a little and rare in nature. It has a half-life of ($t_{1/2}$= 3.92s), which is very little and disappears after a short period from the formation of Radon (^{220}Rn). It also does not reach long distances because of its short half-life of ($t_{1/2}$=55s). The most important yoke of Radon is ^{222}Rn, its half-life is ($t_{1/2}$= 3.82day), and it can move for a large distance from the point of its formation [13]for this reason Radon is considered a health danger.

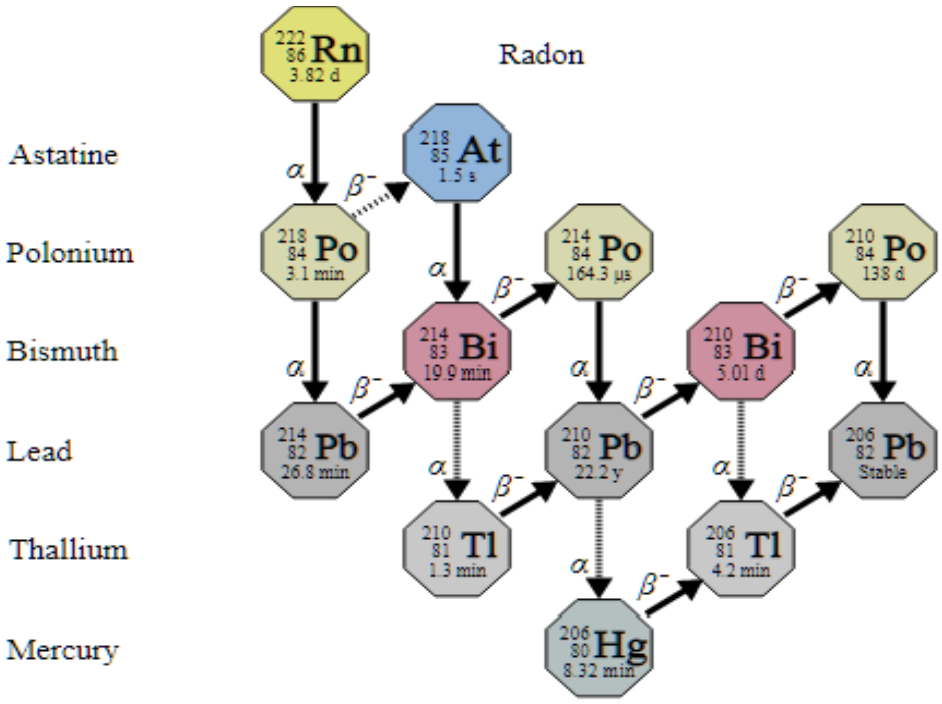

Figure (1.5): Radon(^{222}Rn) decay chain[4]

1.5 Healthy Radon Dangers

Radon-222 is an inert element at a higher support point, atomic number 86, and this makes it one of the noblest elements. It arises from the alpha decay of radium (^{226}Ra) in the Uranium (^{238}U) series, which itself decays into polonium (^{218}Po) with a half-life of ($t_{1/2}$= 3.82day), making it the most stable isotope [14] and the last element to decay is lead (^{206}Pb) as in figure (1.5), as the decay products of Radon react chemically and can stick to walls and floors [9]. The dangers of Radon were discovered by scientists, where it was found that the cause of the death of miners in 1980 is their exposure to high levels of Radon, where it found that Radon can accumulate inside homes and buildings to concentrations up to tens of times greater than the external concentration [15]. The radionuclides of Radon are responsible for more than half of the radiation dose that enters the human body (natural, and industrial) [16]. Radon gas leaks through the atmosphere and soil and rapidly decomposes and produces harmful alpha particles [17] and enters the body of the teeth through ingestion and inhalation.

During the inhalation process, Radon gas enters through the trachea into the lungs and sticks to it. Once deposited in it, two of the decay products of Radon (^{218}Po and ^{214}Po) transfer the majority of the dose to the lung, releasing alpha particles and causing lung cancer. Studies indicated that miners showed increased chromosomal aberration in blood lymphocytes.

These risks are not due to Uranium exposure only, but the most ban is due to the nuclides resulting from the decay of Radon figure (1.6) [18],[19].

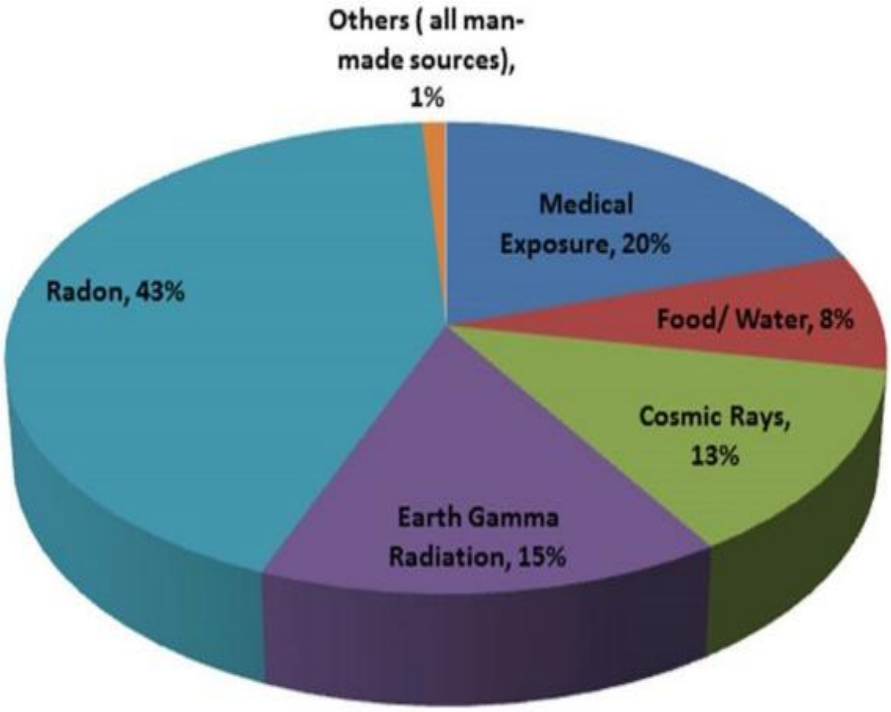

Figure (1.6): Sources and distribution of average exposure to the world population[20].

1.6 Previous Studies

There are several studies in which the radioactive elements of biological samples (blood, bones, tissues, and others) were measured. We will address many studies in which the radioactive elements of blood samples were measured using the nuclear track fission technique as follows:

Wagner et al. (2010) Determination of the concentration of Uranium in blood samples taken from people living near the Fernald Feed Materials Production center functioned as a Uranium processing facility from1951to1989,and potential health effects among residents living near this plant were investigated via the Fernald Medical Monitoring Program(FMMP). the results of 8216adult (FMMP) participants 4187(51%) had low cumulative Uranium exposure,1273 (15%) had moderate exposure, and 2756 (34%) were in the high(40.50 Sievert)cumulative lifetime Uranium exposure category [21].

Al-Hamadany et al. (2011) measurement of radioactive contamination in blood samples for cancer diseases in places (Al-Taji, Abu-Graib, Al-Hurriyah, New Baghdad and Al-Sader town), using the nuclear pathway detector CR-39, where it was found that the number of samples contaminated with Uranium was 48 samples representing 54.5% of the total number. Where the concentration of Uranium in the blood is less than or equal to 0.115 ppm [22].

Tawfiq et al. (2013) used fission track analysis (FTA) with CR-39 SSNTDs to determine Uranium concentrations in the blood samples of occupational and non-professional workers, both male, and female in some Iraqi provinces. It was found that the concentrations of Uranium for professional workers in the Ministry of Science and Technology in Baghdad in blood samples that ranged between (0.26-1.90) ppb were higher than that of non-professionals (1.74-0.28) ppb. Furthermore, they reported that Uranium concentrations in female samples were higher than Uranium concentrations in male samples [23].

Al-Hamzawi et al. (2013) measured the concentration of Uranium in blood samples selected from southern Iraq using the track detector CR-39. It was found that the Uranium concentration of the exposed persons is higher than that of the control sample. Also, they found that the concentration of Uranium in females is higher than in males [24].

Al-Hamzawi et al. (2013) measurement of Uranium concentration in blood samples taken from leukemia patients and a group of healthy people from three main governorates in southern Iraq (Basra, Muthanna and Dhi Qar) using the CR-39 pathway detector. They found that the concentration of Uranium in the blood samples of cancer patients ranged between (0.78 - 2.47)ppb, and in healthy people from (0.32 -1.47) ppb. It has also been found that the Uranium concentrations in blood samples of the exposed group are higher than those of the control group [25].

Al-Hamzawi et al. (2014) determined the Uranium concentration in blood samples taken from healthy and cancer patients, using the CR-39 detector in Basrah, Muthanna and Dhi Qar governorates. In healthy samples, the concentration of Uranium in blood samples ranged from 2.3 to 0.77 ppb, while the concentration of Uranium in patient samples ranged from 4.51 to 1.84 ppb, as it was discovered that the concentration of Uranium in cancer patients is higher than in healthy people [26].

Al-Hamzawi et al. (2014) have applied fission-track technology to determine the concentration of Uranium in blood samples of people from Basrah city, using track detector CR-39. These results were compared with samples from the Babylon governorate. The results showed that the Uranium concentration of blood samples of people from Basrah governorate is higher than blood samples from Babylon governorate [27].

Salih et al. (2016) measured the concentration of Radon in the blood and urine of female cancer patients. The samples were collected at a clinic (Health Center) of University Sains Malaysia (USM), Palau Penang, Malaysia. This study was conducted to assess the health risks. The quantity of Radon in blood samples ranged from (417-714) Bq m^{-3}, whereas the concentration of Radon in urine samples was (149-289) Bq m^{-3}, indicating a link between Radon and cancer [28].

Messier and Serre (2016) studied the risks of Radon gas in groundwater and its effect on lung and stomach cancer in North Carolina, and through this study, they found that exposure to Radon groundwater has an odds ratio of 1.24 (95% CI=1.03, 1.49), which means groundwater Radon, increases the likelihood of Stomach cancer. [29].

Battawy et al. (2017) calculated the concentration of Uranium in blood samples from central and northern Iraq of people working in the field of radiation using the CN-85 track detector. They found that the concentration of Uranium is higher among workers in the X-ray unit 1.310ppb, (males 62 years old, they have 42 practical experience in the unit) with a lower concentration of 1.037ppb than in (22-year-old females with two years experience) [30].

Rasheed (2017) measured the concentration of Uranium in human blood samples in Iraq for patients and healthy people with leukemia, and by using the track detector CN-85, the result was an increase in the percentage of Uranium in blood samples of people with cancer resulting from the military wars 1991-2003. The concentration of Uranium in healthy people ranged from (0.077-0.216) ppb and ranged in patients (1.330 - 1.960) ppb. [31].

Hassan et al. (2019) determined the levels of alpha particles in blood samples in the Karbala governorate for cancer patients by using the track detector CR-39. In comparison to controls ($p < 0.05$), patients had a substantial increase in alpha particle emissions, according to the study. Mean concentrations of Radon and Uranium concentrations were 64.3±25.92 Bq/m^3 and 1.4±0.58 ppm. Male patients had a significantly lower rate of Uranium concentrations than female patients. Finally, the findings of this investigation revealed a strong relationship between Radon and Uranium concentrations [32].

Abed et al. (2019) measured the concentration of Uranium in blood samples of patients with renal failure in Al- the Muthanna Governorate using the track detector CR-39. They pointed out that the concentration of Uranium ranged from (0.119 ppm, to 0.31 ppm,) for the group with kidney failure disease, while the healthy group was (0.117-0.199) ppm. The concentration of Uranium in the

blood samples of patients with renal failure is higher than in the healthy group [33].

Showardet and Aseood, (2019) measurement of alpha particles for leukemia patients in Babylon province using the CR-39 track detector and alpha particles emissions. The highest concentration in the blood of leukemia patients was taken from the city centers at 13.98±0.94 Bq / m^3. The lowest concentration is collected from Al-Mudhatia 5.24±0.54 Bq/m^3. The concentration in male blood samples is higher than in females, as there is a relationship between the age of the patient and the concentration of alpha particles in human blood, and the results show the highest concentrations in the blood. [34].

Showardet and Aseood. (2020) calculated the concentration of Uranium in blood samples collected in Babylon Governorate using the CR-39 track detector. They found that the concentration of Uranium in the city center was higher, reaching 1.09 ±0.22 ppb. They also found that gender and occupations have an effect by increasing the concentration of Uranium in the blood [35].

Kadhim et al. (2020) measured the concentration of Uranium in blood samples of different sexes and ages of some Iraqi people, using the CR-39 nuclear track detector, where the concentration of Uranium in blood samples ranged between (0.39 - 5.14) ppb, where the rate of Uranium concentration in males was less than in females [36].

Stojsavljević et al. (2021) determined the concentration of Uranium in the blood samples of thyroid patients of the Serb population. The concentration of Uranium was 15 times higher in the population compared to the other population group from around the world. Countries that did not suffer from war, while similar results were observed in countries that directly suffered from wars[37].

Asker et al. (2021) measured the Radon concentration in the urine of cancer patients, as samples were collected from the Kirkuk Tumour Department and using the CR-39 track detector, The results illustrated that the highest concentration of Radon is Bq.m^{-1}, as well as the lowest concentration of Radon, is Bq.m^{-1}where they found that the Radon levels that were measured are within the normal limits [38].

Aziz et al. (2021) calculated the concentration of Uranium in the blood of cancer patients in Salah al-Din Governorate using the CR-39 detector. It was found that the average Uranium in the blood of cancer patients ranged between (1.738 - 7.03) ppm while the healthy group ranged between (0.302-2.332) ppm [39].

1.7 The Aim of the Study

Determine the concentration of Uranium and Radon in blood samples different of patients (Leukemia, Digestive system, and Kidney) human living in from Karbala governorate and compare them with the values calculated in different local and international regions and with the ratios by some international organizations. As well as estimating the relationship between the increase in these percentages of the previously mentioned elements with the possibility of developing cancer, as well as knowing the effect of age, gender and location on the concentration rates of both Uranium and Radon.

2.1 Introduction

A high level of radiation can affect human cells and result in biological and physiological changes that include changes in genes, chromosomal aberrations, cancer, mutations, genetic effects, loss of tissues and organ functions in the human body [3]. This leads to its death or modification, causing DNA damage as shown in figure (2.1). DNA damage may occur, but without killing the cell. This damage can be completely repaired. But if it is not repaired, it produces what is called a cell mutation, which is in the form of continuous cell divisions, which in turn is called cancer. But if the affected cells are those cells that transmit genetic information to children, there is a high possibility of genetic abnormalities. Whereas when the number of damaged cells is too large, this leads to malfunction or death of the damaged organ [40].

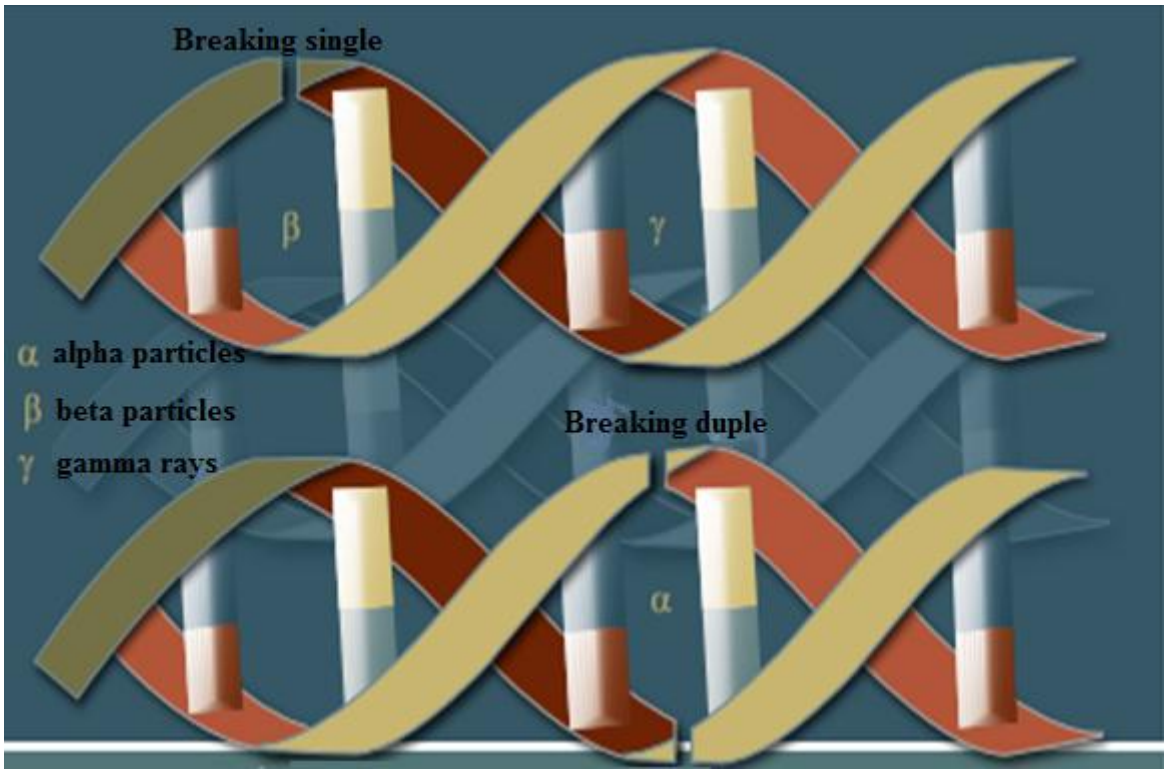

Figure (2.1) Radiation damage to the DNA strand [40]

When cells die or are damaged, health effects occur, for example, skin burns, impaired fertility, or hair loss. These symptoms appear when the radiation threshold is relatively high and the symptoms increase as the dose exceeds the threshold. High doses of 50 Gy damage the central nervous system to death within a few days. Within 8 Gy people show symptoms of radiation sickness such as nausea, vomiting, diarrhea, intestinal cramps, dehydration, salivation, fatigue, apathy, lethargy, fever, sweating, lowering blood pressure, and headache. Small doses may not cause damage to the digestive system, but they can cause death after a few months, mainly due to bone marrow damage. About half of those who receive doses of 2 Gy suffer from vomiting after about three hours of exposure, but this is rare in doses less than 1 Gy. The amount of radiation used depends on the condition and the type of cancer to be treated. Typical doses for curing solid tumors range from 20 to 80 Gy per tumor, but the dose is dangerous. It is too large for the patient, so it is given in the form of repeated fractions of up to 2 Gy and this fractionation process allows cells with healthy tissues to recuperation, while cancer cells are killed due to the lack of efficiency in recuperation after radiation exposure[40].

2.2 Radiation Effects The High Doses (Acute) and Low Doses (Chronic)

Radiation-induced biological effects are typically split into two groups. High radiation doses received over brief times result in the first category's acute or short-term effects. The second category entails prolonged exposure to low doses of radiation that results in chronic or long-term effects. Low doses tend to harm or alter cells, whereas high doses typically cause cell death. When cells are killed in large quantities, tissues and organs can suffer damage. This may then result in Acute Radiation Syndrome(ARS), a rapid whole body reaction. No body organ is immediately harmed by low doses given frequently over a

long period of time. Low radiation doses affect cells at the cellular level, and the effects may take years to manifest [41]. Table (2.1) shows the effect of a high radiation dose

Table (2.1): The effect of high radiation dose[41]

High Dose Effects	
Dose (Rad)	Effect Observed
15 - 25	Blood count changes in a group of people
50	Blood count changes in an individual
100	Vomiting (threshold)
150	Death (threshold)
320 - 360	LD 50/60 with minimal care
480 - 540	LD 50/60 with supportive medical care
1,100	LD 50/60 with intensive medical care (bone marrow transplant)

2.3 Blood

Blood is one of the main components of the human body, and some of its components are constantly changing, while new cells are created every 120 days. Our blood circulates throughout our body, supplying the cells with nutrients and oxygen that are necessary for life. Additionally, it moves metabolic waste out of those cells. Blood cannot be substituted. It cannot be manufactured or made. The only source of blood for patients who require a blood transfusion is kind blood donors. White blood cells, red blood cells, and platelets are suspended in a protein-rich fluid called plasma that makes up blood. The normal total volume of blood in circulation makes up about 8% of body weight (5600 mL in a 70- kg man). Plasma makes up about 55% of this volume [42].

2.4 Composition of Blood

Blood contains the following components:

A- 45% of it contains

1-Red blood cells (erythrocytes)

2-White blood cells (leukocytes)

3-Platelets (Thrombocytes).

B- (55%) of its remaining fluid is plasma.

2.4.1 Red Blood Cells (Erythrocytes).

Hemoglobin is transported through the bloodstream by red blood cells or erythrocytes. They are produced as biconcave disks in the bone marrow. Mammals, lose their nuclei before they enter the bloodstream. They remain in the bloodstream of humans for, on average, 120 days. For men and women, respectively, the normal red blood cell count is 5.4 million/μL and 4.8 million/μL. The volume of blood that is made up of erythrocytes, or the hematocrit, can also be used to conveniently express the number of red blood cells. The average human red blood cell has a diameter of 7.5 μm, a thickness of 2 μm, and contains 29 pg of hemoglobin. Thus, there are approximately 900 gm of hemoglobin and 3*1013 red blood cells in the circulating blood of an adult man[42].

2.4.2 White Blood Cells (Leukocytes)

In a typical microliter of blood, there are 4000–11,000 white blood cells. The majority of these are granulocytes, also known as polymorphonuclear leukocytes (PMNs). Horseshoe-shaped nuclei in young granulocytes develop into multilobed nuclei as the cells age. Most of them have neutrophilic granules (neutrophils), but some also have eosinophilic and basophilic granules that stain with acidic dyes (basophils). The other two cell types typically found in peripheral blood are monocytes, which have an abundance of a granular

cytoplasm and kidney-shaped nuclei, and lymphocytes, which have large round nuclei and scant cytoplasm. Together, these cells give the body strong defenses against infections and tumors caused by bacteria, viruses, and parasites [42].

2.4.3 Platelets (Thrombocytes)

Small, granular bodies called platelets collect at the sites of vascular injury. They are 2-4 μm in diameter and are without nuclei. The half-life of circulating blood, which is about 300,000/μL, is typically 4 days. The massive bone marrow cells known as megakaryocytes produce platelets by pinching off pieces of cytoplasm and releasing them into the bloodstream. The blood is circulating with between 60% and 75%of the platelets that have been extruded from the bone marrow, with the remainder being mostly in the spleen. The platelet count rises after splenectomy (thrombocytosis) [42].

2.5 Units of Radiation

In the context of historical development and research in the field of radioactivity, many units have been proposed and used as shown in table (2.2) [43].

Tabel 2.2: Units of Radiation[43]

Unit	Quantity	SI Equivalence
Becquerel (Bq)	Radioactivity unit.	1 Bq = 1 s^{-1}
Curie (Ci)	An ancient non-SI unit of radioactivity.	1Ci = 3.7 × 10^{10} Bq 1Bq = 27 × 10^{-12} Ci
Gray (Gy)	Absorbed dose in units (SI).	1Gy = 100 rad
(rad)	Radiation absorbed dose.	1 rad = 0.01 Gy 1 rad = 0.01 J/kg
Sievert(Sv)	Equivalent dose.	1 Sv = 100 rem .
(rem)	Röntgen equivalent man	1 rem =0.01 Sv

2.6 Uranium

Uranium is a naturally occurring radionuclide in the Earth's crust. The element was named after the planet Uranus, the seventh planet in our solar system, by researcher Claproth in 1789 in Pitchblind, or what is now known as the Czech Republic, while investigating mineral samples in silver mines. However, it was eventually determined that the material identified by Claproth was Uranium oxide, not pure Uranium. Eugene Melchior Belgot, a French scientist, isolated Uranium in its pure form in 1841[44]. It is a heavy, ductile, silver-colored metal, lightly magnetic, and whitish, with less hardness than steel, and it reacts with water in its fissured state [45]. It is found in small quantities in soil, rocks, water, plants, animals, and humans. Also after that other radioactive elements (polonium and radium) were discovered by Marie and Pierre in 1898[45].

Uranium is found naturally in food, air, water and the human body. The human body contains approximately 56 µgm of Uranium, 32 µg (56%) in the skeleton, 11 µgm in muscle tissue, 9 µgm in fat, 2 µgm in blood and less than 1µgm in lung, liver and Kidneys [46]. Uranium is present in nature and is on a large scale (solid, liquid, gaseous compounds) where it combines easily with the elements to form Uranium oxides, silicates, carbonates and hydroxides [47]. The amount of Uranium that enters the human body is approximately about (1-2) µgm from food and (1-5) µgm in water [48]. The largest percentage of Uranium that enters the human body comes from plant sources of food, especially vegetables and grains [49], [50]. Uranium is a heavy metal whose absorption by foods and liquids cannot be avoided. Mammals are considered to be more sensitive to Uranium [51]. When Uranium is absorbed into the human body, it moves to the cellular fluid and then moves through the blood to all parts of the body. The largest amount of Uranium comes through drinking water, as it was proven through studies conducted in northern Germany that 20% of the

studied cases water containing Uranium [52]. Uranium is considered one of the heavy, toxic and radioactive elements, and it comes after calcium in terms of its percentage in the human body as in building bones[46]. All isotopes of Uranium emit alpha radiation and are positively charged ions, and because of their large size they quickly lose their kinetic energy, and this is reflected in their ability to penetrate alpha particles whose energy ranges from (2-5) MeV, Which penetrates a distance of 4 cm in the air and 50 μm in the soft tissues. Its penetration ability is very limited, and therefore the real danger of Uranium comes primarily from the internal influence and not the external influence [53]. Figure (2.2) shows the behavior of Uranium in the human body.

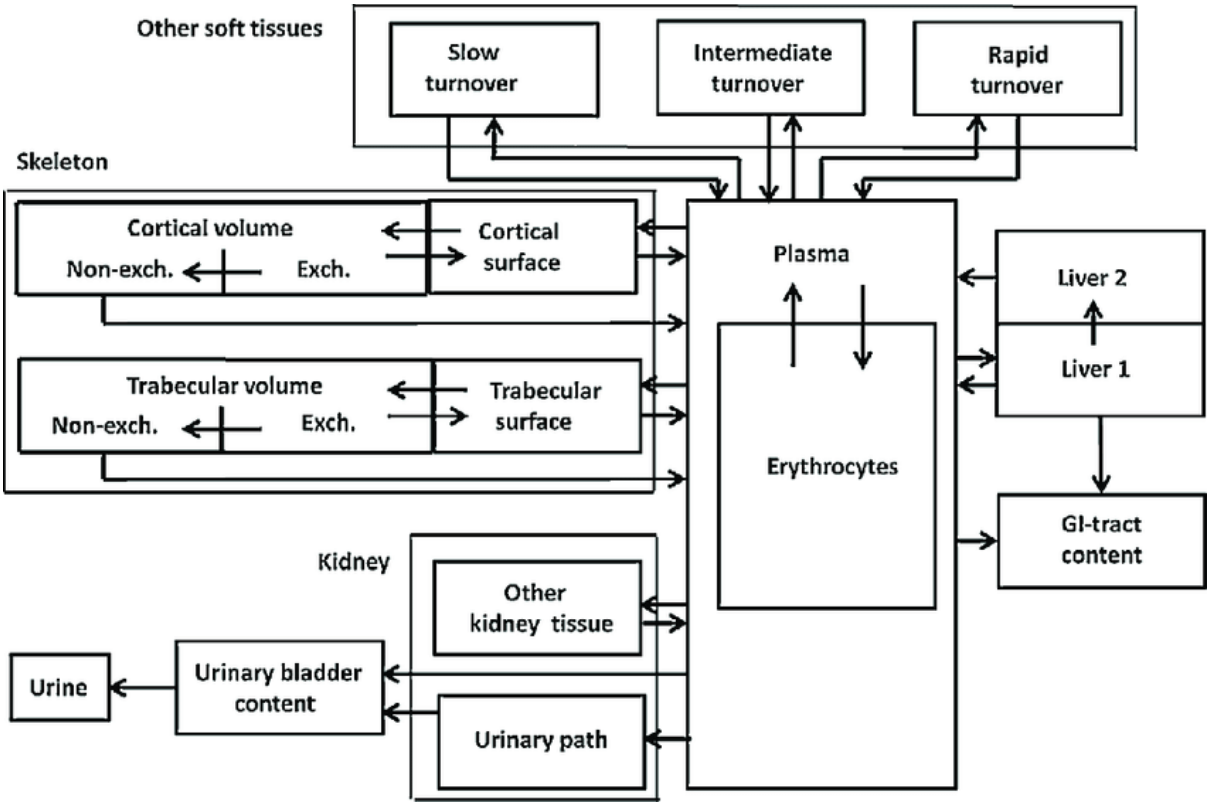

Figure (2.2): The behavior of Uranium in the human body[54].

2.7 Solid-State Nuclear Track Detectors

During the past 25 years or so, the method of solid-state nuclear track detectors (SSNTDs) has grown [55] at first, it had no actual practical applications, but over time it had many applications in space physics, the study of samples, mineralogy and geology, cosmic physics, fission, medicine, biology and many more. This was confirmed by many studies and research[56]. D. A. Young discovered solid-state nuclear track detectors while working at the atomic energy corporation in Harwell in England, where crystals adhered to Uranium paper and when these crystals were irradiated with thermal neutrons, tracks were formed. They were discovered after being treated with a chemical detection device. It was found that the number of these pits exactly matches the estimated number of fission fragments, as it is clear that the craters were formed as a result of fission fragments [57]. Through the studies conducted, it was found that the effects that have been formed are characterized by:

1- Tracks are produced only by highly ionized particles

2- Produced in poor electrical insulators and semiconductors

3- The tracks formed are not affected by light or when exposed to high levels of X-rays, ultraviolet rays, etc.

Due to its durability and simplicity, it has made it into many applications [58]. The detector is initially homogeneous and there are no restrictions in shape and size. It is usually a high polymer [59], inorganic glass [60], or a single crystal material such as mica [61] or, bromargyrite (AgBr) and is thin enough to display in electron microscopy the trackways caused by ionization or collision of atoms as these particles change from the detector structure [62]. The radiation-damaged regions are almost continuous along the particle tracks and can be developed for viewing in an optical or electron microscope.

2.8 Types of Solid Nuclear Track Detectors

The nuclear track detector is divided into two types: inorganic detector and organic detector.

2.8.1 Inorganic Detectors

Detectors that do not include carbon and hydrogen in their composition, most notably mica, which is characterized by high sensitivity to charged particles of large mass and records the tracks of particles and fission fragments. As well as its high stability for recording particles at temperatures of 400^{O}C, an acid solution is used Hydrofluoric HF with a concentration ranging from (1-48%) at room temperature[56]. As for glass, it is one of the good detectors that are used to detect neutrons, especially in nuclear reactors, because of its high tolerance and ability to sense fission fragments. Some types of detectors are inorganic as shown in table (2.3).

Table 2.3: Some types of inorganic detectors [63]

NO.	Detectors Types	Chemical Composition
1	Zircon	$ZrSiO_4$
2	Quartz	SiO_2
3	Mica(Biotite) Mica (Muscovite)	$K(Mg, Fe)_3\ AISi_3O_{10}\ (OH)_2$ $KAI_3Si_3O_{10}\ (OH)_2$
4	Fluorite	$CaF_{10}(OH)_2$
5	Soda Lime Glass	$23SIO_2\ 5Na_2O\ 5CaO\ Al_2O_3$
6	Olivine	$MgFeSiO_4$
7	Calcite	$CaCo_3$

2.8.2 Organic Detectors

The organic detectors are compounds in which carbon and hydrogen are inserted to create a covalent bond between their atoms, they are polymeric materials (polymers) that consist of large molecules with small repeating units linked with each other called monomers. Carbon hydrogen bonds and breaks

these bonds easily when exposed to radiation and an organic detector have greater analysis ability and sensitivity than an inorganic detector that has lower threshold energy than an inorganic detector. The solid-state nuclear detector used in our study is CR-39, and we will mention in detail its specifications and characteristics, and the following is a table showing some types of these detectors [64],[65]. Some types of detectors are organic as shown in table (2.4).

Table 2.4: Some types of organic detectors[66]

NO.	Detectors Types	Chemical Composition	
1	Polyester(HB Pa IT)	$C_{17}H_9O_2$	
2	Polyimide	$C_{11}H_4O_4N_2$	
3	Cellulose, Cellulose Nitrate Cellulose Triacetate	 $C_6H_8O_9N_2$ $C_3H_{14}O_3$	 (CN) (CT)
4	Polycarbonate (Lexan, Makrofol)	$C_{16}H_{14}O_3$	(PC)
5	Plexiglass	$C_5H_8O_2$	
6	Polyallyl glycol Carbonate	$C_{12}H_{18}O_7$	(CR-39)

2.9 Features of the Nuclear Track Detector

1- They are inexpensive and easy to use.

2 -They are strong and of different sizes (from very small to large).

3- It is not sensitive to light.

4- The tracks recorded on the detector are permanent and do not disappear, so they can be recorded at any time, unaffected by weather conditions such as temperature, pressure, and humidity.

5 Not sensitive to X-rays, Gamma, and Beta rays.

6- It can be used as a detector, as it differs from glass and plastics because it records the tracks of alpha particles and the track of fissionable fragments, unlike plastic and glass record the fission tracks only.

7- The energy and charge of the detectors are better than that of nuclear emulsions.

8- Quick techniques can be used with these detectors to calculate the number of tracks produced

9- Commercially available [67].

2.10 Biological Applications

The nuclear trace detector is used by digging the path of possible effects in making a hole by etching latent damage trails has also helped in making “filters". Through the conditions of the experiment, it is possible to control the size, number, location, and shape of these tracks, Such filters have been used in filtering cancer cells from human blood [68],[69].

2.11 CR-39 Nuclear Track Detector

There are many types of solid-state nuclear track detectors, but in this study, the CR-39 nuclear track detector was used. polyallyl diglycol carbonate (PADC), known as CR-39, was discovered in 1978 by researchers (Cartwright, Price and Shirk) [70] It is one of the most important organic detectors that do not contain nitrogen. It is one of the most sensitive plastic materials for nuclear track recording. The CR39 detector is the most common detector on a commercial scale, and it can detect alpha energies from zero to 77 MeV. It is a polymeric material shortened by CR-39 derived from Columbia Resin [71], which is a chain of short polyallyle connected by carbonate diethylene glycol groups in a three-dimensional network [72]. The chemical formula for the CR-39 detector is shown in figure (2.3) [63].

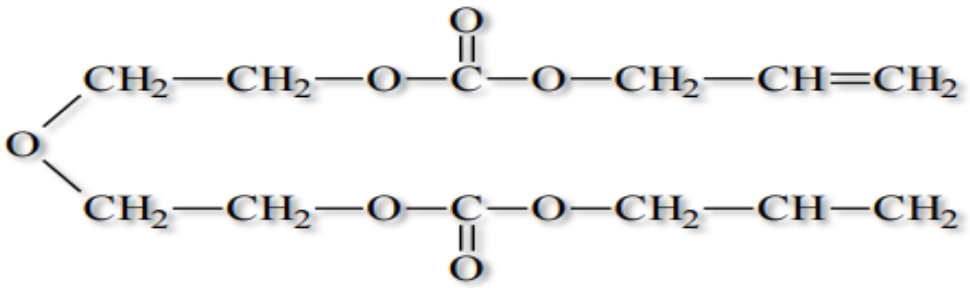

Figure (2.3): The molecular formula for the CR-39 detector [63]

The CR-39 is produced in sheet form by a monomer with some types of primer in a frame. The chemical structure of the CR-39 monomer is with a molecular weight of 274.2707 g/mol, whose molecular structure saturates the chain as shown in figure (2.3). The chain-like structure is generally more sensitive to radiation than other structures. The density of CR-39 is 1.32 g/cm^3. The refractive index has a value of n=1.504.[73] The detector can be drilled in NaOH or KOH mode. Tracks appear on the surface of the etched detector from 20 keV to 1.02MeV [74]. The CR-39 detector can record the number of tracks, positions, and directions (zenith angle θ, azimuth angleϕ), but can also be known by knowing the charge, mass, and energy of the track parameters, so CR-39 is one of the most widely used solid-state nuclear track detectors [74].

2.11.1 Characteristics of the CR-39 Nuclear Track Detector

The nuclear track detector has many properties, the most important of which are [75]:

1. High optical purity and transparency
2. homogeneous substance
3. High analysis ability
4. Environmentally stable, unaffected by weather conditions such as temperature and humidity
5. It is sensitive to damage by heavy ions
6. It is an amorphous polymer

7. It does not dissolve in abrasive chemical solutions, but it dissolves in a solution of etching a layer of it to show the tracks of alpha particles

2.12 Thermal Neutron Source

For research and development, thermal neutrons are produced by nuclear fission in nuclear reactors that act as a source of continuous neutrons. There are three groups of thermal neutron sources, which are nuclear fission reactors, particle accelerators, and radioisotopes. Nuclear reactors are not suitable for recording nuclear tracks. Most of them use radioactive isotopes in recording nuclear tracks. Neutron sources contain (radioactive isotopes) emitting alpha particles. The Beryllium $^{9}_{4}Be$ was used in this study as a neutron source. It is one of the most important targets because of its return High in neutrons has a half-life (about 433y). Neutrons are generated through the (2-1) reaction between particles and the target material, where α- particles are produced through the decay of Americium ^{241}Am. Neutrons are produced on a large scale with an average energy level of about 4.2 MeV to a maximum of 10 MeV [76].

$$^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + n + E \text{.....(2-1)}$$

α- particles, Beryllium, carbon, neutron, energy

In this study, we used a neutron flux of Americium-Beryllium ^{241}Am-$^{9}_{4}Be$ source 3×10^{5} n cm^{-2} s^{-1} to irradiate the samples (blood samples). The ^{241}Am is a heavy element and it is an automatic emitter of α-particles that covers the element $^{9}_{4}Be$. It is one of the light elements that interact with alpha particles as well in the previous equation The irradiation system consists of a radioactive source, which is in the form of a rod surrounded by paraffin, which is used to moderate fast neutrons and convert them into thermal neutrons, which in turn

interact with Uranium, producing fission fragments that leave tracks on the CR-39 detector [77].

2.13 Recordable Particles in SSNTDS

When heavy charged particles enter, it produces radioactive in the insulating solid material, the effect is along the track of the body. Damaged materials can be drilled with a chemical detector if the damaged materials are of sufficient density where the tracks appear in the form of holes along the track. A chemical detector attacks the impacts formed in all directions. Then the size of the inner diameter of the channel (the hole) increases. When the size of the channel (the diameter of the channel) is equal to the size of the wavelength of light, the channel becomes visible with an optical microscope. The diameter of the underlying tracks of the fragments is estimated to be several nanometers. If the density of the materials damaged by radiation is not sufficient, these materials cannot be drilled by a chemical detector to form the drilling track. This material is considered insensitive to particles and tracks cannot be recorded with it. The density of the damaged material is not only related to the type of the falling particle Z but also its speed V and energy E. When the particle's velocity and energy are high, the interaction between the particle and the solid material (the atomic electrons of the atom) is very little. At that time, the damage caused is very little due to radiation. It is not possible to dig the formed region by the detector to form the track. But if the velocity of the particles is less, the interaction time of the particles with the electrons of the material increases gradually. Gradually the effective charge of the particle decreases, and then its ability to cause damage decreases. The ability of the particles to produce effect decreases, at some speeds. The particle can produce a track accessible only in a limited area of energy and velocity. The particle cannot produce any tracks, above or below this region. SSNTD can record the trajectories of particles,

protons, fission fragments, heavy ions, and neutrons when choosing appropriate detector materials [78].

2.14 Types Etching

There are several types of etching methods, used to show the effects of the alpha particle tracks on the surface of the detector, but in this study, we use chemical etching. It is a kind of etching [78].

1. Chemical etching
2. Electrochemical etching
3. Etching tracking kinetics

2.14.1 Chemical Etching (CE)

It is the basic technique in this study, which is used to detect the tracks of nuclear particles in solid materials (CR-39 detector). The two basic requirements for chemical etching are the etching and etchant device.

2.15 Chemical Etching Conditions

2.15.1 Etching

The etching is a specific chemical substance, which reacts mainly with the effects of the passage of charged particles in the air. Sodium hydroxide was used in this study for the chemical etching process of the detector. In order for the etching process to occur, three conditions must be met [68].

1- Chemical used for etching

2- Duration of etching

3- Temperature during etching

The etching is specific to each type of detector. Each detector has an etching period, the concentration of the abrasive solution, and the temperature

difference from the other. The increase in temperature and concentration of the solution leads to an increase in the pits of the tracks significantly. Usually, this leads to damage to the detector. Increasing the etching time causes the diameters of the etching tracks to be larger [78].

2.15.2 Etching Device (Water Bath)

It is a device that is made by maintaining constant etching conditions. Usually, the container containing the chemical (NaOH) is kept in a closed container, to prevent the exchange of materials from inside and outside to ensure that the concentration of the chemical solution (NaOH) is constant [78].

2.15.3 Etching Temperature

The temperature throughout the container must be constant and homogeneous. Increasing the temperature leads to an increase in the etching rate exponentially. Any small temperature change greatly affects the rate of etching. When using an optical microscope to calculate trajectories in solid-state nuclear track detectors, the temperature accuracy is in the range of (10-100 ^{O}C) [79].

2.16 Track Etching Geometry

The angle of the falling particle is one of the most important reasons on which the track etching geometry depends, as no tracks can form on the surface of the detector when the angle of incidence of the particle is less than the critical angle (the angle between the sample particles and the surface of the detector) [80]. There are two types of chemical reactions involved in the engraving process:

1- Drilling with damaged materials.

2- Drilling with undamaged materials from the detector (bulk) [79].

The formation of tracks depends on the speed of each V_T and V_P where V_T is the average speed of digging the track for the damaged material, and V_P is the average speed of digging the track for loose materials. No track is formed on the surface of the detector. Figure (2.4) shows the work of CE in a solid amorphous material that has an orthogonal particle track from the detector.

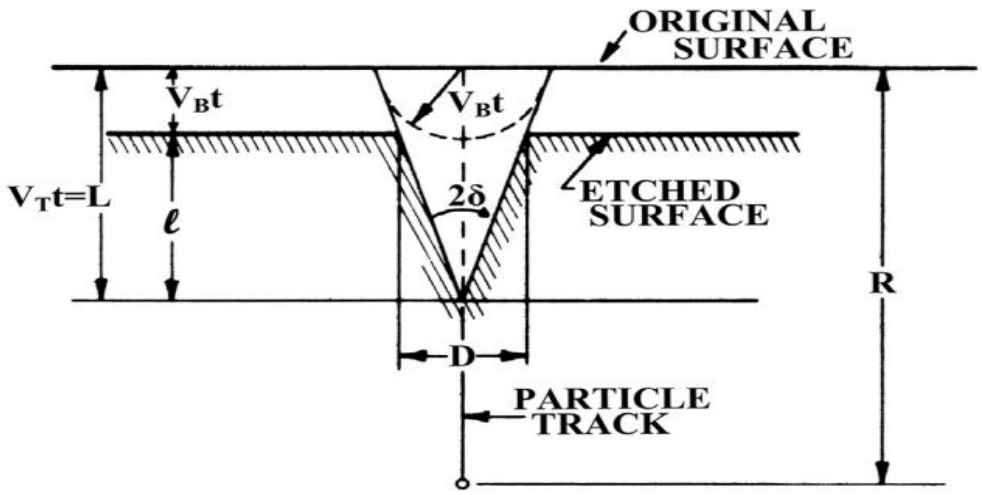

Figure (2.4): The geometry of the track etching in a solid amorphous material [79]

Where V_T is the track etching rate of the damaged material in a period of t as shown in figure (2.4), V_B is the rate of track etching of the bulk material in a period of t. The conical shape formed is at a depth ($L = V_T * t$) below the original surface of the detector. A layer is removed from the surface of the detector by etching at the rate of $V_B * t$ to form a new surface. The value ($l = V_T - V_B$) represents the length of the visible tracks of the detector.[59]

From figure (2.4) it is possible to calculate the diameter of the track when it is $\theta = 90$ using the equation [79].

$$d = 2V_T t\sqrt{\frac{V_T - V_B}{V_T + V_B}} \qquad \text{.....(2-2)}$$

or

$$d = 2V_T t\sqrt{\frac{V-1}{V+1}} \quad \text{.....(2-3)}$$

Where $V = {}^{V_T}/_{V_B}$ is the etching rate ratio.

When $\theta \neq 90^o$, the constant track abrasion rate V_T can find the main axis of the engraved track and the D diameter of the track is given by, [79]

$$D = \frac{2V_T t\sqrt{V^2-1}}{V\sin\theta+1} \quad \text{.....(2-4)}$$

Minor axis to open.

$$D = 2V_T t\sqrt{\frac{V\sin\theta-1}{V\sin\theta+1}} \quad \text{.....(2-5)}$$

In practical studies, where V_T is very little constant often yields satisfactory results, although in general, V_T changes along the particle's journey [79].

2.17 Critical Etching Angle

The critical angle θ is the angle formed as a result of competition between V_B and V_T. As completed in figure (2.5) the particle entered the surface of the detector with an angle of θ. $V_T t$ is the etching rate due to the detector's length in time t (for the damaged part) $V_B t$ is The average thickness that is removed from the surface of the detector (bulk). $V_T t \sin\theta < V_B t$ As in figure (2.5-A) no etched track is formed due to the removal of the track by etching. If $V_T t \sin\theta > V_B t$ the track formed is conical as in (C and D). If $V_T t \sin\theta = V_B t$ is the critical state of the tracks formed on the surface of the detector, then referred to as the angle θ where the angle is the critical angle θ_c [81].

$$\theta_c = \sin^{-1}\frac{V_B}{V_T} \quad \text{..... (2-6)}$$

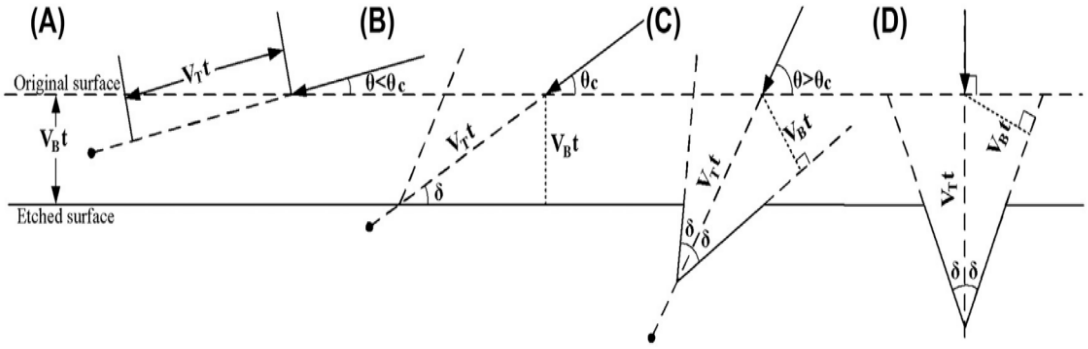

Figure (2.5): Particles fall on the surface of the detector with different tracks [81].

2.18 Techniques for Measuring Critical Angle

2.18.1 Direct Measurement of the Half-Angle of a Cone

Through figure (2.4) we see that $\theta = \delta$ where δ is half the angle of the cone. This means that if we can measure the radius of the angle of the cone, we can determine the critical angle θ_C and V_T provided that we know the value of V_B [79].

2.18.2 Direct Measurement of the Critical Angle

Through figure (2.5-B), we notice that the critical angle θ can change with the change of the angle of the falling particle. The tracks begin to appear on $\theta = \delta$. With this technique, it is possible to measure the critical angle for several Muscovite mica detectors (4^0 30`), obsidian ($26^0$ 00`), U-2 reference glass (31^o45`), Lexan polycarbonate ($2^O31$`), and macrogol polycarbonate (3^O00`) [81].

2.19 Etching Efficiency

Etching efficiency (ω) is the ratio between the number of recorded tracks and the number of particles emitted from the sample that fall on the surface of the detector. Etching efficiency depends on both V_T and V_B and can be calculated from the following equation [82].

$$\text{ع} = 1 - \frac{V_T}{V_B} \qquad \text{.....(2-7)}$$

or

$$\text{ع} = 1 - \sin\theta \qquad \text{.....(2-8)}$$

3.1. Introduction

In this chapter, we review each of the methods, materials, and devices used to complete this study, which includes sample collection and experiments used to determine Uranium and Radon concentrations in blood samples of cancer patients.

3.2. Study Area

Iraq has been exposed to much radioactive contamination during the wars that passed from (1991-2003). Radioactive pollutants have accumulated inside the dental body resulting from direct and indirect exposure to radiation. The Karbala governorate was used as a study site, where the area of Karbala governorate is about 5.034km2 and its population is about 1,012,356 people, according to the statistics of the Central Statistical Organization for Statistics / Directorate of Population and Manpower Statistics / Iraq for the year 2015[83]. Figure (3.1) show the geographical location that was used in the study.

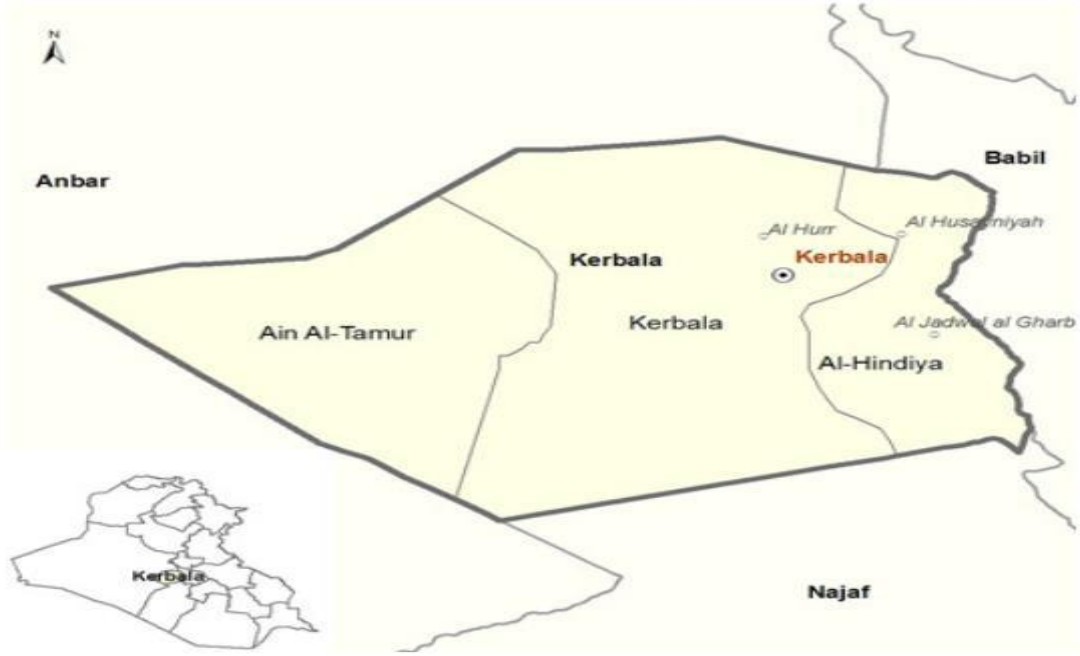

Figure (3.1): The geographical location that was used in the study[83].

3.3 CR-39 Nuclear Track Detector

The CR-39 (English-made) track detector was used in this study. The details of the detector were discussed in the previous chapter.

3.4 Radioactive Source

In this study, the thermal neutron radiator source ^{241}Am-$^{9}_{4}Be$ with neutron flux 3×10^{5} n cm^{-2} s^{-1} was used for the samples beam consisting of the source rod ^{241}Am-$^{9}_{4}Be$ surrounded by paraffin to moderate the fast neutrons and convert them into thermal neutrons. The alpha particles released from americium react with Beryllium covering americium according to the following reaction. Thermal neutrons interact with the Uranium present in the samples to produce fissionable fragments that leave tracks on the surface of the detector. Figure (3.2) shows the process of irradiation of samples and the mechanism of placing samples in the neutron source [76].

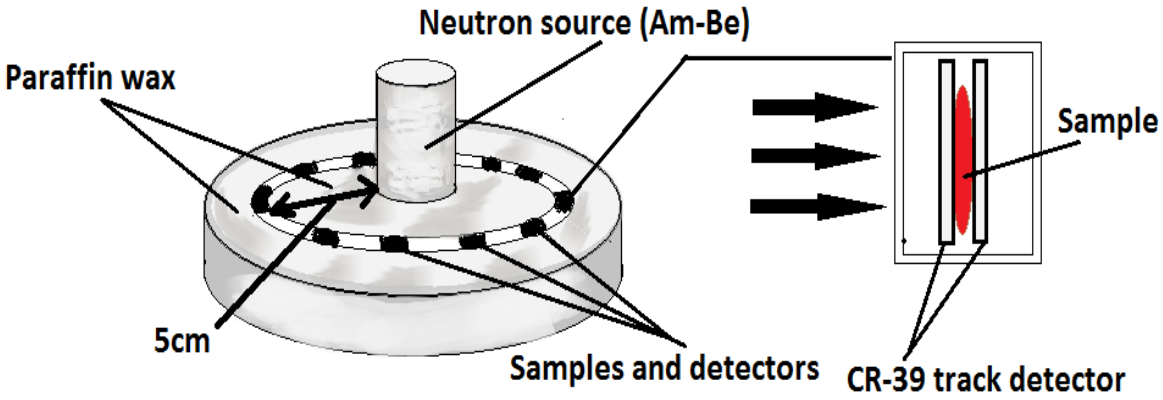

Figure (3.2): Irradiation of samples and the nuclear track detector in the neutron source.

3.5 Water Bath

The water bath (Schwabach, Germany) was used for each of the samples. The water bath consists of a basin with water and is equipped with an electric heater in order to maintain the temperature of the etching solution in a constant way. The device was calibrated and it was found that the temperature of the device is ± 1 C. Etching was done under a temperature of (70± 1°C) using water as a liquid for the water Bath [9]as shown in figure (3.3).

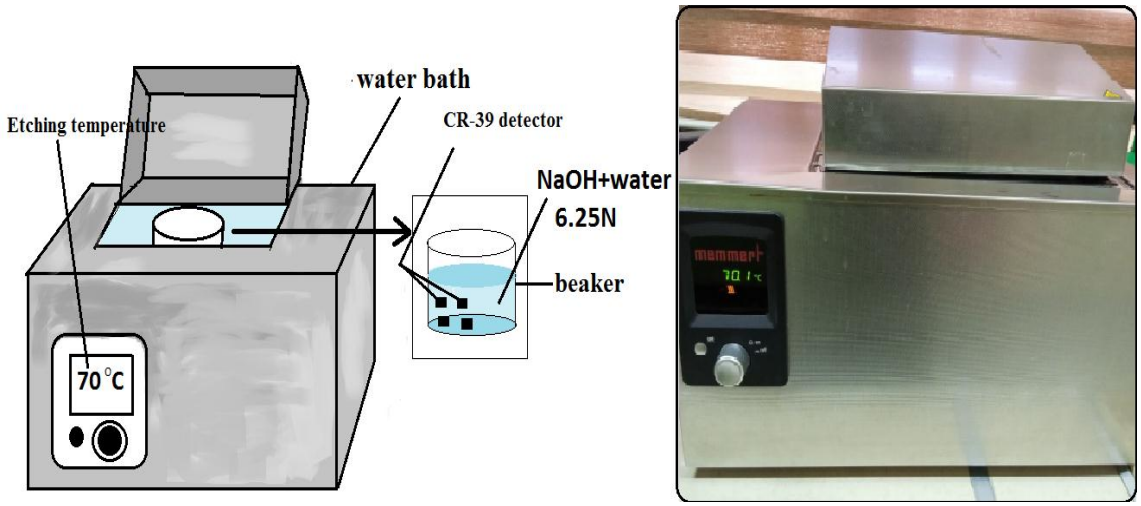

Figure (3.3): The water bath

3.6 NaOH Solution

The NaOH solution used to etch the CR-39 nuclear track detectors was prepared at a concentration of 6.25 N. By mixing 200 ml of water with 50 gm NaOH, as shown in figure (3.5), the solution was prepared in a glass graduated volumetric vial through the following equation[9].

$$N = \frac{W_{NaOH}}{V_w} * \frac{1}{\omega_{NaOH}} \qquad \text{.....(3-1)}$$

Where V_w is the volume of the solution used to dissolve NaOH, ω_{NaOH} is the Molecular weight of NaOH, N is the solution concentration, W_{NaOH} is the NaOH weight

The magnetic stirrer was used to homogenize water with NaOH precisely for 5 minutes as shown in figure (3.4).

Figure (3.4): The magnetic stirrer.

Figure (3.5): The balance used to measure the weight of samples.

3.7 Optical Microscope

An optical microscope (KRUSS-mbl 2000) was used with a magnification of 400X and a viewing area of unit cm^2. This microscope was used to view the tracks of Uranium fission in blood samples in the CR-39 detector as shown in figure (3.6).

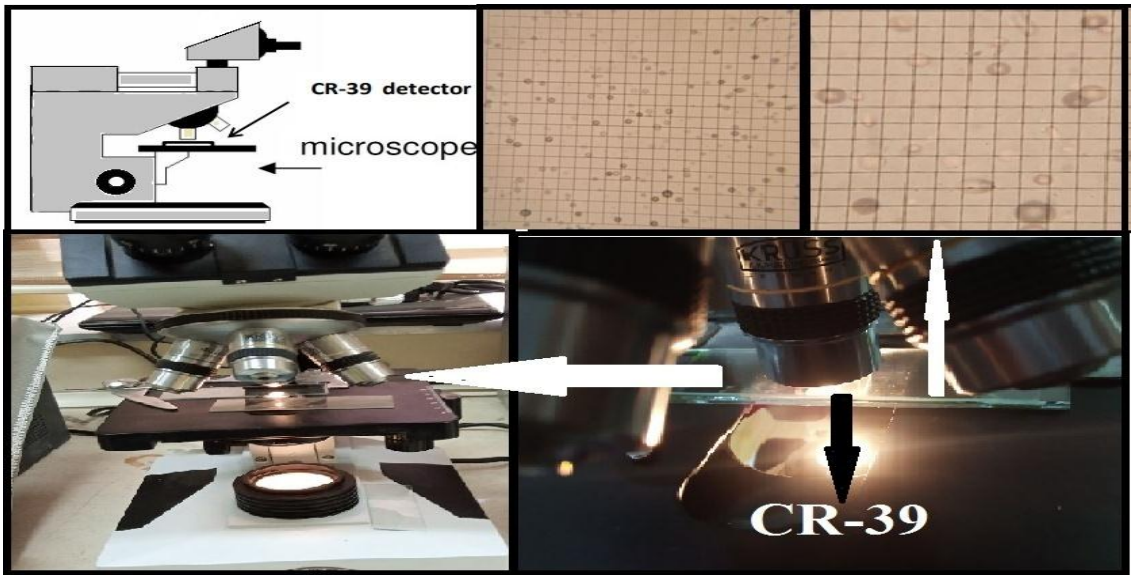

Figure (3.6): Optical microscope.

3.8 The Method of Work

3.8.1 Sample Collection

In this study, 115 blood samples were taken from male and female volunteers. The patient group included 75 samples of cancer patients collected from the Oncology Center at Al-Hussein Hospital in Karbala Governorate. While the healthy group was 40 samples of healthy people living in the same governorate. It was confirmed by taking the information of the healthy group that they had no previous history of exposure to Uranium.

3.8.2 Experimental Method

The experimental method for checking the concentration of Uranium is the same as that used by other researchers [33]. Blood samples were collected from study participants, 10 healthy volunteers, and 75 patients. The collected blood samples were placed in EDTA tubes containing heparin, which prevents blood clotting. Using the micropipette device, a droplet volume of 35 µl of samples was placed over the solid-state nuclear track detector CR-39, the dimensions (1×1) cm^2. The samples are left for about an hour to dry, and then another detector is placed on top of them so that the samples are covered by the detector on both sides. The samples were arranged in the form of a strip of a detector, and they are surrounded by adhesive tape on both sides to ensure that the sample is preserved and not moved, as well as for its numbering figure (3.7).

Figure (3.7): The samples prepared for irradiation

When completing the preparation of the samples, the samples were placed in the neutron radioactive source $^{241}Am-^{9}_{4}Be$ with flux 3×10^5 n cm^{-2} s^{-1} the samples were placed at a distance of 5 cm from the radioactive source for a period of 7 days as in the figure (3.8).

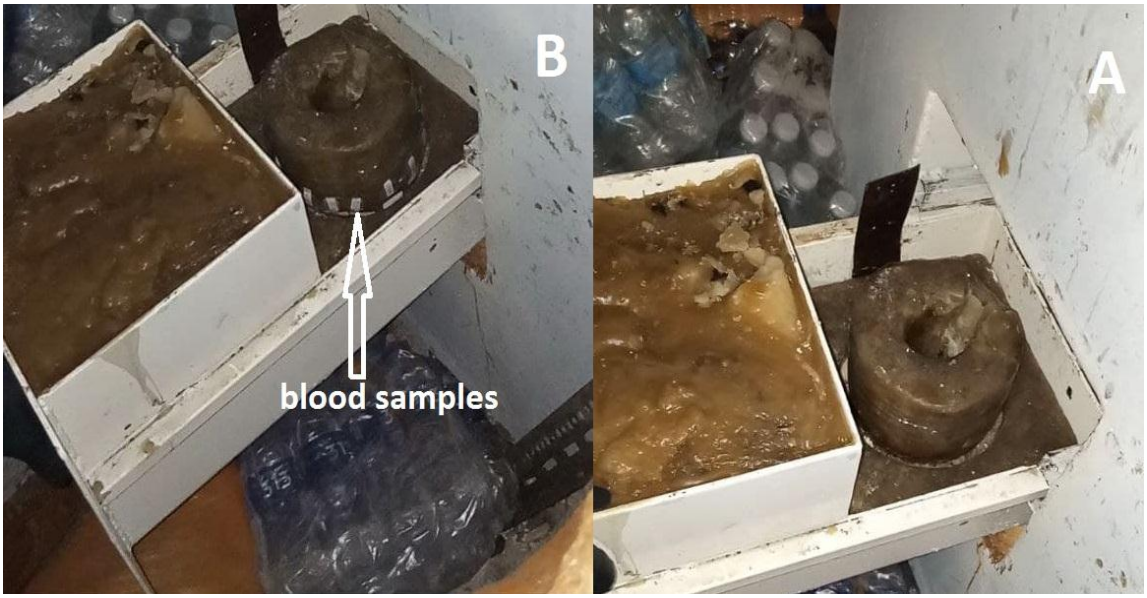

Figure (3.8): **A**- Source of radiation **B**- Irradiation of samples

After irradiation for a period of 7 days, the samples were taken out from the radioactive source. The detectors were washed with distilled water very carefully. The blood samples on the detector were removed properly. After that, the detectors moved to the etching stage using sodium hydroxide solution. The detector was placed in NaOH solution at a concentration of 6.25 N at a temperature (70±1) ^{o}C for 5 hours as in figure (3.3). The after etching of samples, the detectors moved to the counting stage using an optical microscope (KRUSS-mbl 2000). The detectors were placed under an optical microscope with a magnification of 400x to calculate the number of visible tracks on the detector due to the fission of Uranium present in the blood samples, as shown in figure (3.9). Steps of the working method for measuring the concentration of Uranium as shown in figure (3.10)

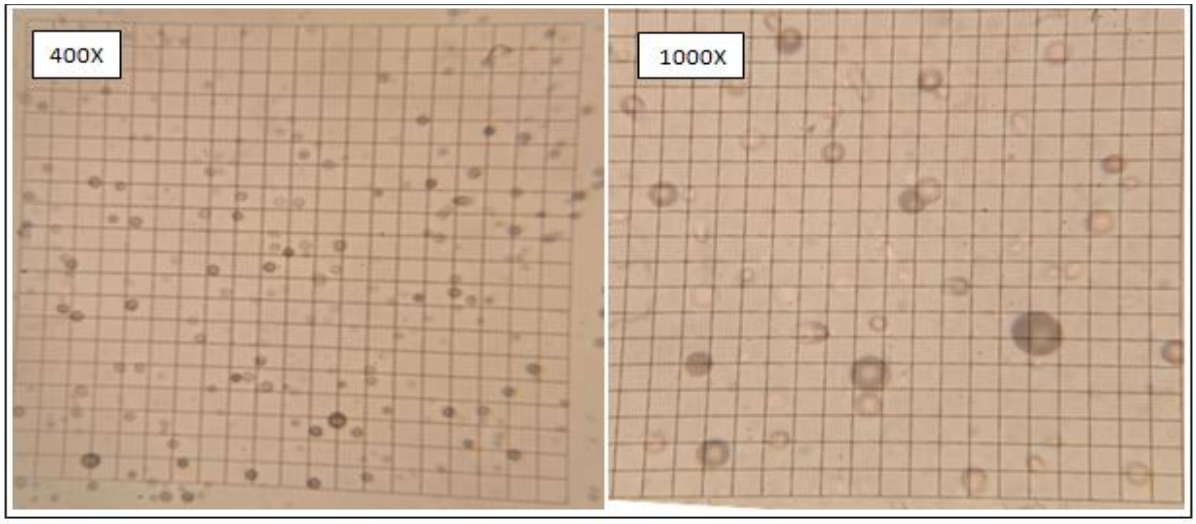

Figure (3.9): The effects produced in the CR-39 detector, which are visible by the optical microscope.

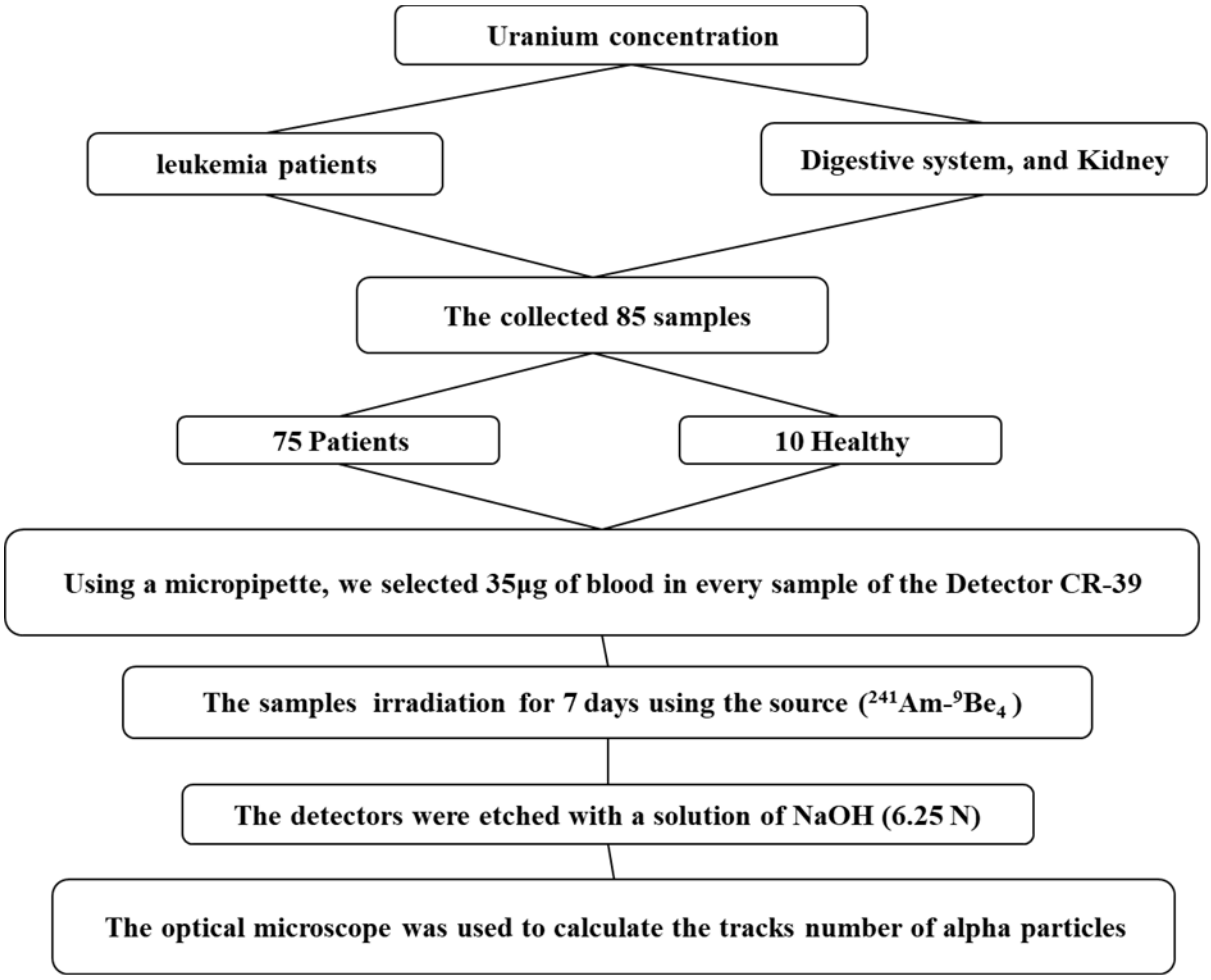

Figure 3.10: Steps of the working method for measuring the concentration of Uranium

Blood samples were collected from study participants, 30 healthy volunteers, and 50 patients. Samples were placed into an anticoagulant tube (EDTA) and then into plastic Petri dishes as shown in figure (3.11), which were then encoded with numbers. The samples were then dried for 24 hours at 37°C in an electric incubator, after the samples were dried, they were crushed using a manual mill, as shown in figure (3.12). The samples were then sieved to obtain a homogeneous powder using a fine sieve. For 60 days, 0.5 gm of fine blood powder was stored in knowing tubes with CR-39 as shown in figure (3.13). For detection of alpha particles of Radon, the CR-39 detector used has an area of (2.5 x 2.5) cm^2 and a thickness of 1 cm. The diameter of the tube used for storage is 3.5cm and the sample height is 3.2 cm detector figure (3.14).

Figure (3.11): The samples in Petri dishes and their numbering.

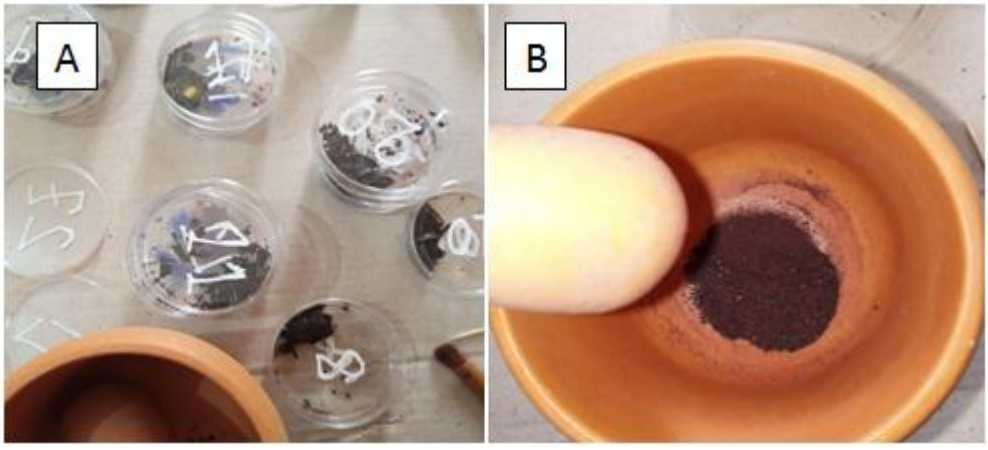

Figure (3.12): (A) Dried blood samples and (B) Manual mill.

Figure (3.13): The sample storage.

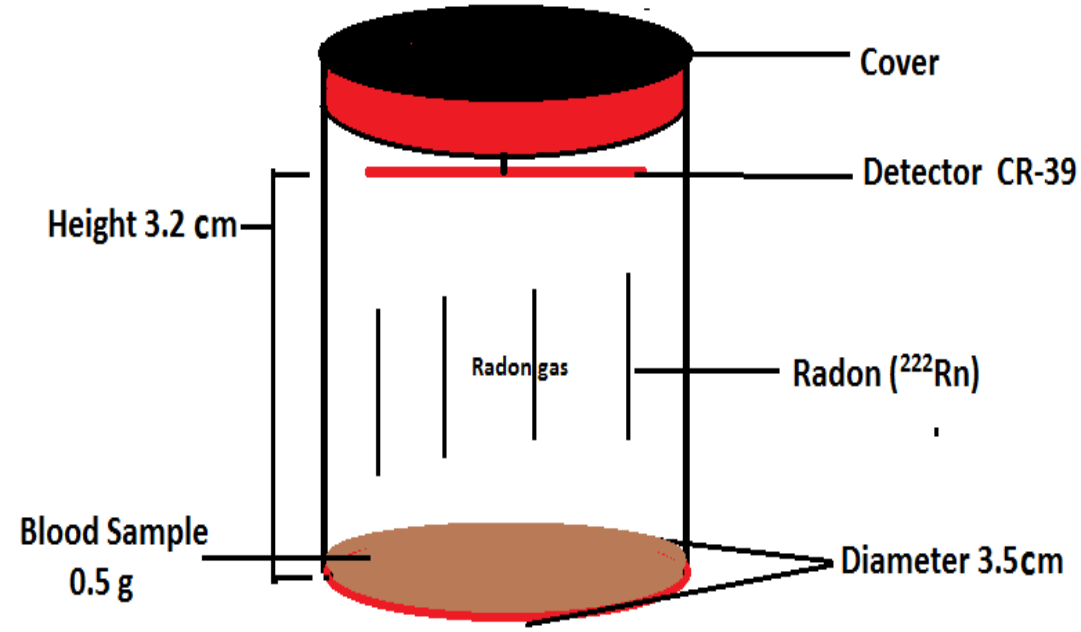

Figure (3.14): The diagram of a tube for measuring alpha particle concentration.

The 60 days, the detectors were carefully extracted from the storage tubes to avoid any scratches that might occur. After that, the detectors moved to the stage of etching using NaOH solution. The detector was placed in a NaOH solution with a concentration of 6.25 N at a temperature of (70 ± 1) ^{o}C for 8 hours as in figure (3.3). After etching the samples, the detectors moved to the counting stage using an optical microscope the figure (3.15). Figure (3.16) steps of the working method for measuring the concentration of Radon

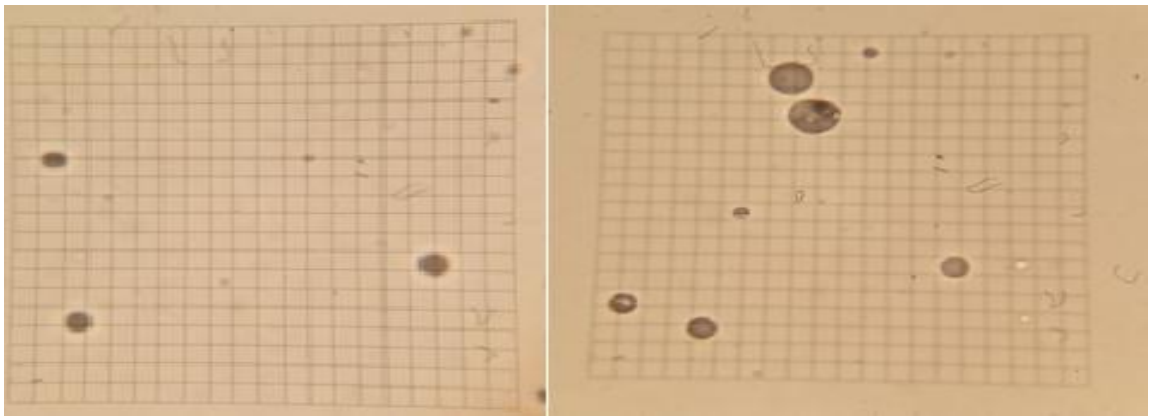

Figure (3.15): The effects caused by the CR-39 detector under an optical microscope.

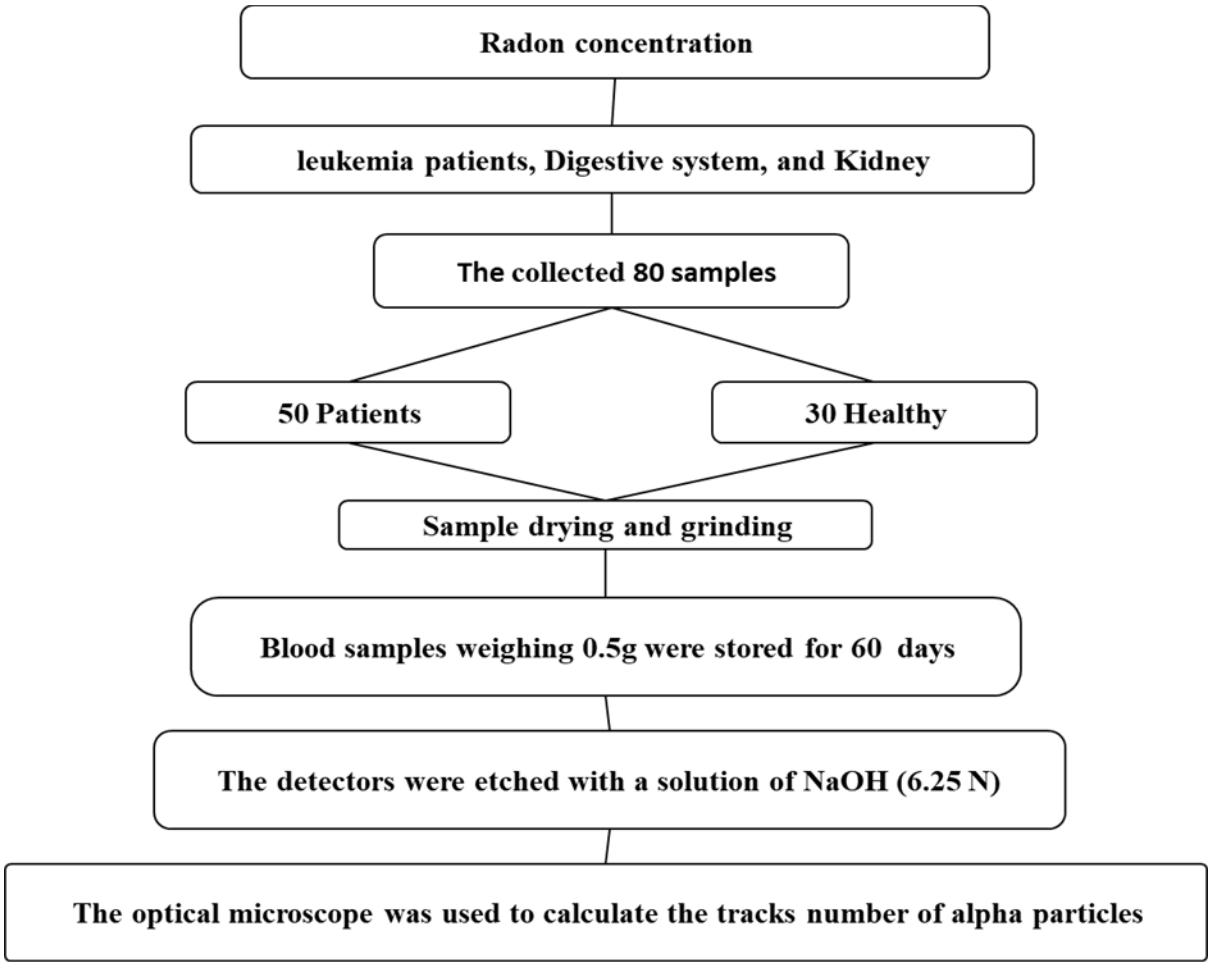

Figure (3.16): Steps of the working method for measuring the concentration of Radon

3.8.3 Uranium Concentration

The concentration of Uranium in blood samples was measured and verified by comparing the tracks recorded on the CR-39 detector with the tracks of standard samples through the following relationship equation.

$$\frac{C_U}{C_{St}} = \frac{P_U}{P_{ST}} \quad \text{.....(3-2)}$$

$$C_U = P_U / Slope \quad \text{.....(3-3)}$$

C_U is the Uranium concentration of unknown samples. C_{St} is the Uranium concentration for standard samples. P_U is the density of tracks for the unknown samples. P_{ST} is the density of tracks for the standard samples as shown in figure (3.17)[27].

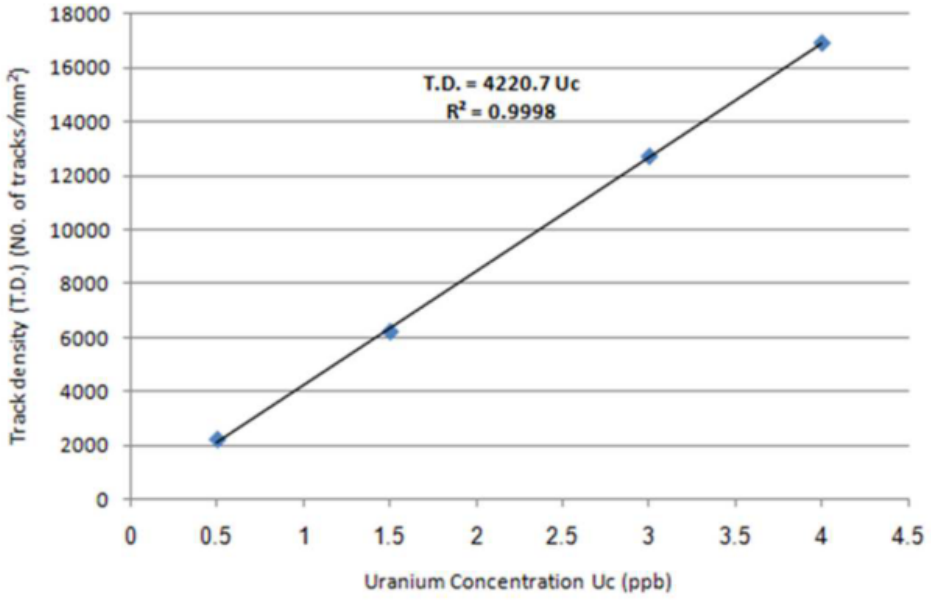

Figure (3.17): The relationship between the density of tracks and the concentration of Uranium in standard samples [27].

The concentration of Uranium in blood samples was determined by the CR-39 detector by comparing the concentration of standard samples with the samples used in the study. The density of the resulting tracks P in the detector was calculated through the following equation.

$$P_U = \frac{N}{A} \quad \text{.....(3-4)}$$

N is the number of tracks of Uranium samples, A is the viewing area of the optical microscope [84].

3.8.4 Radon Concentration

The concentration of Radon in blood samples was measured and verified by counting the number of tracks recorded on the CR-39 detector, where the density of tracks P_{Rn} in the samples was calculated through the equation given by [85],

$$P_{Rn} = \frac{N}{A} \quad \text{.....(3-5)}$$

Where N is the number of tracks of Radon samples. A is the viewing area of the optical microscope.

The concentration of Radon in the air inside the tube was determined by [86],

$$C_{Rn} = \frac{P_{Rn}}{K\,t} \quad \text{.....(3-6)}$$

where C_{Rn} is the Radon concentration in air tube (Bq/m^3), P_{Rn} is the density of tracks in blood samples (Tr./cm^2), t is the exposure time (60 days) and K is the calibration factor or sensitivity factor (Tr/cm^2 .d per Bq/m^3) defined by [87],

$$K = \frac{1}{4} r(2\cos\theta_{\mathbf{c}} - \frac{r}{R_\alpha}) \quad \text{.....(3-7)}$$

Where r is the radius of the storage tube (1.65cm), $\theta_{\mathbf{c}}$ is the critical angle of the CR-39 detector (35^o)[86], R_α is the indicate the range of alpha particles in the air (4.14cm). According to eq.(3-8) the value of calibration factor K was 0.0443 (Tr/cm^2 .d per Bq/m^3).

The Radon concentration in the samples can be calculated through the equation by [87].

$$C_{Rn}^{S} = \frac{C_{Rn} h\,t\,\lambda}{\ell} \quad \text{.....(3-8)}$$

C_{Rn} is the Radon concentration in the air tube (Bq/m^3), h is the distance between the sample and the detector (3.2cm), λ is the decay constant 0.1814 d^{-1}, t is the exposure time (60 d), ℓ is the sample thickness (0.2 cm).

The standard deviation coefficient $S.D$ of the concentration of Radon and Uranium can be calculated through the following equation[88].

$$S.D = \sqrt{\frac{1}{n}\sum_{1=1}^{n}(x - \overline{x})} \quad \text{.....(3-9)}$$

Where is $\overline{x} = \frac{1}{n}\sum_{i} xi$ .....(3-10)

4.1. Introduction

The tracking technique was used in calculating the concentration of radioactive elements by a group of researchers [89],[90], where the concentration of Uranium and Radon was measured in selected samples of cancer patients in the Karbala governorate using the nuclear fission technique with the CR-39 solid-state nuclear track detector. The statistically processed using Statistical Package of the Social Sciences (SPSS) was used to analyze all the obtained results. A t-test was performed using an independent sample to determine the level of probability (P).

The samples 25 were collected from Al-Hussein Medical City Hospital in Karbala Governorate from pediatric leukemia patients, their ages ranged from 9 months to 12 years, in front of the healthy group were 5 samples from children as in table (4.1).

Table 4.1: Statistics for the number of samples, their ages, and gender in leukemia patients.

Gender	Frequency	Age (y)	Average Age(y)
patients female	12	0.9-11	5.8
patients Male	13	1.7-12	6.8
healthy female	3	2.5-5	3.8
healthy Male	2	2-5	3.5

The samples (50) were collected from Digestive system and Kidney cancer patients, their ages ranged from 1.6 to 81 years, and included 22 samples from females and 28 from males, while a healthy group consisted of 10 samples from males and females as in table (4.2).

Table 4.2: The number of samples and their gender in the Digestive system, and Kidney.

Gender	Frequency	Age(y)	Average Age(y)
patients female	22	3-80	54.2
patients Male	28	1.6-75	50
healthy female	6	2.5-62	24
healthy Male	4	2-40	19.25

4.2 Uranium Concentration Measurement

4.2.1 Measurement of Uranium Concentration in Pediatric Leukemia Patients

The concentration of Uranium in the blood samples of pediatric leukemia patients and the healthy group was found using equations (3-3), (3-4), and (3-5), where the lowest concentration of Uranium in the sample leukemia patients was 0.444 ± 0.092ppb, while the highest concentration was 1.83 ± 0.135ppb as in table (4.3).

Table 4.3:The concentration of Uranium in blood samples of leukemia patients (children).

NO.	Age (y)	Gender	Living	U.con.ppb & S.D
P1	5	Female	AL-Husseiniyah	0.58 ± 0.113
P2	6	Female	AL-Salam	1.32 ± 0.136
P3	3.6	Female	Bab AL-Salam	0.91 ± 0.098
P4	0.9	Female	AL-Hindiya	1.11 ± 0.143
P5	6	Female	Kantara AL-Salam	1.50 ± 0.163
P6	10	Female	Al-Hurr	1.27 ± 0.299
P7	8	Female	Al-Amel	1.18 ± 0.171
P8	11	Female	AL-Ghadeer	1.83 ± 0.135
P9	5	Female	AL-Hindiya	0.55 ± 0.101
P10	7	Female	Al-Taka	0.79 ± 0.134
P11	3	Female	Al-Mohandessin	0.78 ± 0.114
P13	5	Female	AL-Askary	1.15 ± 0.106
P12	3	Male	Al -Zahraa	0.536 ± 0.093
P14	11	Male	Al-Wafa	0.541 ± 0.132
P15	3	Male	Al-Taka	0.733 ± 0.130
P16	9	Male	Al-Hurr	1.311 ± 0.161

P17	7	Male	Al-Hurr	0.541 ± 0.085
P18	4	Male	Imam Ali	0.793 ± 0.103
P19	12	Male	AL-Amn AL-Dakhily	0.835 ± 0.136
P20	7	Male	AL-Hindyai	0.764 ± 0.137
P21	12	Male	Imam Ali	0.606 ± 0.132
P22	2	Male	Al-Ghadeer	0.459 ± 0.127
P23	1.7	Male	AL-Hindiya	0.444 ± 0.092
P24	12	Male	AL-Hindiya	0.607 ± 0.103
P25	5	Male	Feriha	0.715 ± 0.072
Total P.	25			
Minimum				0.444±0.092
Maximum				1.830±0.135
Average				0.874±0.1286

Where the lowest concentration of Uranium in the sample healthy group was 0.249 ± 0.090 ppb and the highest concentration was 0.330 ± 0.104ppb as in table (4.4).

Table 4.4: The concentration of Uranium in blood samples of healthy people

NO.	Gender	Age (y)	Living	U.con.(ppb)&S.D
N1	Female	2.5	AL-Husseiniyah	0.259 ± 0.023
N2	Female	4	Al-Hurr	0.330 ± 0.104
N3	Male	5	Al Ghadeer	0.249 ± 0.090
N4	Male	2	AL-Hindyai	0.306 ± 0.153
N5	Female	5	Al-Hurr	0.251 ± 0.085
Total N.	5			
Minimum				0.249±0.090
Maximum				0.330±0.104
Average				0.279±0.091

From the two tables (4.3) and (4.4), we find that the concentration of Uranium in the group of leukemia patients is higher than in the healthy group, where the rate of Uranium concentration in the patient's group was four times higher than in the healthy group. There was a difference between the concentration of Uranium in the healthy group and the group of cancer patients when performing the independent sample t-test where the value was significant ($p < 0.001$). It was

also observed that the concentration of Uranium in female blood samples is higher than its concentration in males, perhaps because the proportion of blood in females is 4.5 liters, while in males 5-6 liters. [39]. We found that the standard deviation coefficient in the healthy group was less than the group of cancer patients, where the mean deviation was 0.036ppb and 0.364ppb, respectively. As for the average concentration of Uranium, the cancer patients had 0.874ppb, while the healthy group was 0.279ppb, as shown in the figure (4.1).

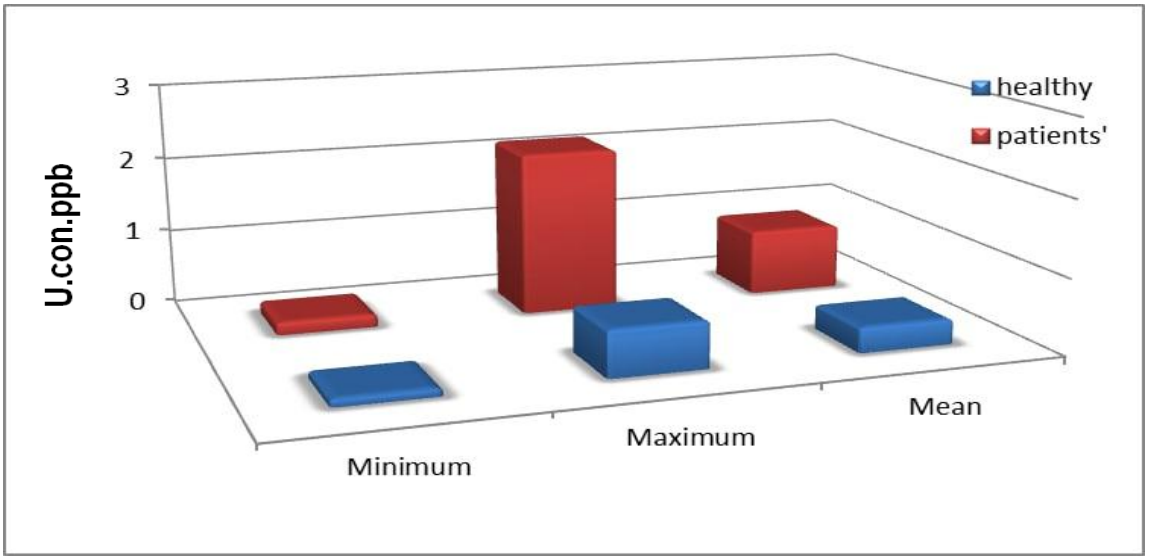

Figure (4.1): The statistic chart of Uranium concentration in leukemia patients and a healthy group.

There is also a relationship between age and Uranium concentration, as we note that the concentration of Uranium in females with an average age of (0.1- 4)y is less than the concentration of Uranium in females with an average age of (4-8)y and, the latter is less than the group whose ages are (9-12) y and the same goes for males as shown in the table (4.5).

Table 4.5: The relationship between Uranium concentration and age in leukemia patients

No.	Frequency	Age(y)	Gender	Average U.con.ppb
1	5	0.1-4	Male	0.64
2	3	5-8	Male	0.67
3	5	9-12	Male	0.78
4	4	0.1-4	Female	0.84
5	6	5-8	Female	1.09
6	2	9-12	Female	1.55

These results suggest a relationship between the sickness and the amount of Uranium in their blood. In the south of the Iraqi governorate, Al-Hamzawi et al. [26] investigated the concentration of Uranium in human (female and male) blood. The study showed that the levels in leukemia patients' blood samples are higher than in healthy people's blood samples [25]. When comparing the results with the values obtained by the researcher[25], we find that the concentration of Uranium in the study samples was lower, as the average concentration of Uranium was (2.87 ± 0.11)ppb. Abed et al. [33] measured the concentration of Uranium in human blood samples, they found that females had greater Uranium levels than males in both healthy and patient people. Also, the results of our measurements are approximate of Koul et al. [91], whose results proved that the rate of Uranium concentration in blood samples of leukemia patients was higher than that of the healthy group.

4.2.2 Measuring the Concentration of Uranium in Patients with Cancer of the Digestive System and Kidneys

The number and gender of samples used in this work, as well as the type of cancer and the number of samples for each case, are all listed in Tables (4.6) and (4.7).

Table 4.6: The number of samples and their gender.

Patient Samples		Healthy Samples	
gender	Frequency	gender	Frequency
Female	22	Female	5
Male	28	Male	5
Total	50	Total	10

Table 4.7: The number of patients and the type of disease.

Disease	Frequency
Colon	16
Esophageal	3
Kidney	5
Pancreas	10
Rectal	10
Stomach	6
Total	50

The concentration of Uranium in the blood samples of the Digestive system and Kidney the lowest concentration of Uranium in the sample of cancer patients was 0.172±0.0352ppb, while the highest concentration was 2.165±0.1459ppb as in table (4.8).

Table 4.8: The concentration of Uranium in cancer patients' blood

No.	Gender	Age(y)	Living	Disease	U.con.ppb & S.D
P1	Female	58	AL-Hindiya	Colon	0.5209 ± 0.1202
P2	Female	44	Ain AL-Tamur	Colon	0.5976 ± 0.2488
P3	Female	80	AL-Walaa	Stomach	0.3865 ± 0.1425
P4	Female	72	AL-Hindiya	Stomach	0.7441 ± 0.109
P5	Female	69	AL-Taiun	Pancreas	0.4739 ± 0.1201
P6	Female	61	AL-Eman	Colon	0.1715 ± 0.0352
P7	Female	59	AL-Amen	Stomach	0.5244 ± 0.1501
P8	Female	56	AL-Hindiya	Pancreas	0.3909 ± 0.1256
P9	Female	46	AL-Hindiya	Stomach	0.5948 ± 0.1252
P10	Female	50	AL-Abassia AL-Sharqia	Colon	0.5807 ± 0.1036
P11	Female	60	Street AL-Najaf	Esophageal	0.5602 ± 0.1272

P12	Female	63	Al-Ghadeer	Esophageal	0.6313	±	0.1413
P13	Female	3	AL-Nedal	Kidney	1.1746	±	0.1629
P14	Female	32	Aoun	Rectal	1.5512	±	0.258
P15	Female	30	AL-Hindiya	Rectal	1.4775	±	0.1228
P16	Female	44	AL-Askary	Rectal	0.9244	±	0.1061
P17	Female	61	AL-Hindiya	Rectal	1.0713	±	0.2643
P18	Female	81	Al-Hurr	Esophageal	0.9853	±	0.1519
P19	Female	70	AL-Askary	Pancreas	1.7569	±	0.2129
P20	Female	59	AL-Molhak	Rectal	1.4262	±	0.2086
P21	Female	50	AL-Husseiniyah	Rectal	1.2672	±	0.1061
P22	Female	45	AL-Husseiniya	Rectal	1.2265	±	0.1259
P23	Male	55	Al-Ghadeer	Colon	0.5527	±	0.0633
P24	Male	38	AL-Askary	Colon	0.5364	±	0.1536
P25	Male	48	AL-Moadafeen	Stomach	0.9678	±	0.0943
P26	Male	48	AL-Moadafeen	Colon	0.71	±	0.2511
P27	Male	45	AL-Abass	Colon	0.6882	±	0.1035
P28	Male	67	Al-Hurr	Pancreas	0.7354	±	0.1616
P29	Male	47	AL-Askary	Colon	0.6825	±	0.1459
P30	Male	73	Shohada AL-Moadafeen	Stomach	0.7441	±	0.2107
P31	Male	44	AL-Hindiya	Colon	0.5137	±	0.1608
P32	Male	64	AL-Hindiya	Colon	0.4493	±	0.142
P33	Male	59	AL-Hindiya	Colon	0.3274	±	0.0578
P34	Male	64	AL-Husseiniyah	Pancreas	0.5836	±	0.103
P35	Male	55	Al-Ghadeer	Colon	0.7496	±	0.1157
P36	Male	35	AL-Amameen	Pancreas	0.4329	±	0.1777
P37	Male	54	AL-Husseiniyah	Pancreas	0.4454	±	0.1045
P38	Male	56	Al-Hurr	Colon	1.2679	±	0.2316
P39	Male	60	AL-Walaa	Colon	0.3879	±	0.0123
P40	Male	75	AL-Hindiya	Colon	0.7003	±	0.1225
P41	Male	50	Al-Ghadeer	Pancreas	0.467	±	0.074
P42	Male	52	AL-Hindiya	Pancreas	0.7107	±	0.2424
P43	Male	1.6	Al-Amel	Kidney	1.7261	±	0.2077
P44	Male	5	AL-Husseiniyah	Kidney	1.6433	±	0.2149
P45	Male	5.6	AL-Askary	Kidney	1.2283	±	0.1316

P46	Male	64	AL-Nawab	Rectal	1.4169	±	0.1273
P47	Male	47	AL-Husseiniyah	Rectal	1.8232	±	0.2063
P48	Male	60	Al-Hurr	Rectal	2.1647	±	0.1459
P49	Male	60	AL-Taiun	Kidney	1.345	±	0.129
P50	Male	70	Aoun	Pancreas	1.0244	±	0.1059
Total P.		50					
Maximum					2.165±0.1459		
Minimum					0.172±0.0352		
Average					0.8812± 0.145		

The lowest concentration of Uranium in the sample of healthy people was 0.104 ± 0.044ppb while the highest concentration was 0.614 ± 0.102ppb as in table (4.9).

Table 4.9: The concentration of Uranium in the blood of healthy people

No.	Gender	Age(y)	Living	U.con.ppb & S.D		
N1	Female	2.5	AL-Husseiniyah	0.259	±	0.011
N2	Female	4	Al-Hurr	0.330	±	0.092
N3	Male	5	AL-Hindiya	0.249	±	0.025
N4	Male	2	Al-Ghadeer	0.306	±	0.108
N5	Female	30	AL-Somoud	0.341	±	0.120
N6	Female	42	AL-Somoud	0.570	±	0.304
N7	Female	62	AL-Somoud	0.614	±	0.102
N8	Female	5	Al-Hurr	0.251	±	0.053
N9	Male	30	AL-Abassia AL-Sharqia	0.104	±	0.044
N10	Male	40	AL-Walaa	0.328	±	0.091
Total N.		10				
Minimum				0.104±0.044		
Maximum				0.614±0.102		
Average				0.335±0.095		

Tables (4.8) and (4.9) show that the Uranium concentration in cancer patients is greater than in the healthy group, with the rate of Uranium concentration in the patient's group being one and a half times higher. In comparison to the healthy group, the patient group is on top. The concentration of Uranium in male blood

samples is also higher than in female blood samples, owing to males being exposed to pollution at a higher rate than females through a job, entering factories and participating in wars. There was a difference between the concentration of Uranium in the healthy group and the group of cancer patients when performing the independent sample t-test where the value was significant $p < 0.05$. As for the average concentration of Uranium, cancer patients reached 0.8812ppb, while the healthy group was 0.335ppb, as shown in figure (4.2).

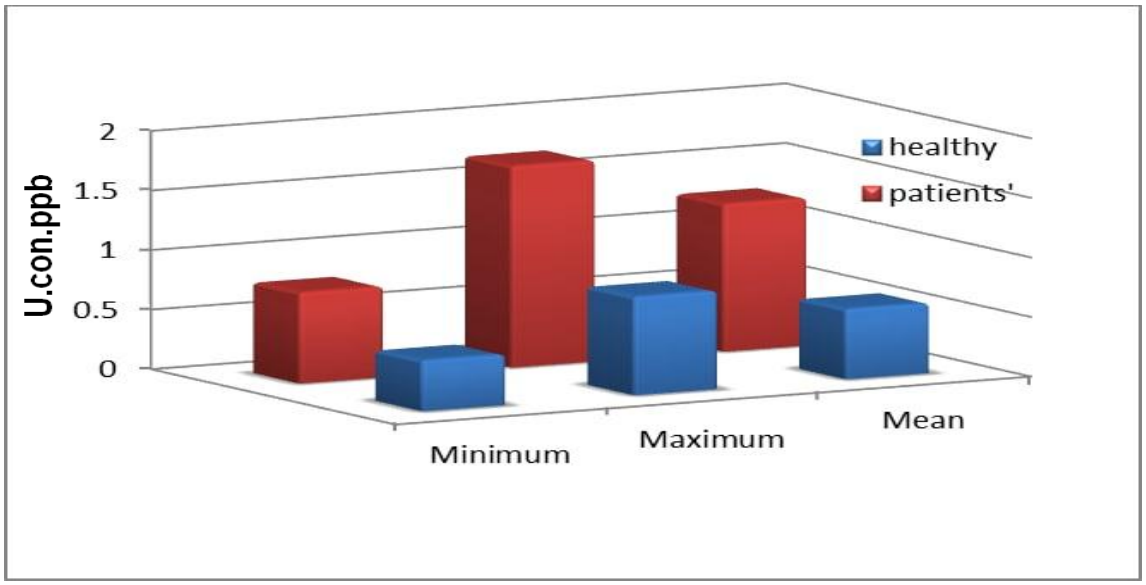

Figure (4.2): The Statistical comparison between blood samples of cancer patients and healthy by unit (ppb).

Through the evidence obtained and found in tables (4.3), (4.4), (4.7), and (4.8) after knowing the location of each sample, it was found that the incidence of cancer in the city center is lower than it is in the outskirts of Karbala city. Rural housing is higher than urban patients, and this is the result of pollution, lack of health awareness, eating and drinking polluted water, and poor food storage, all of which are factors that lead to discoloration and an increase in the concentration of Uranium in the human body.

When comparing the results obtained by the researcher [36], we find, through our study, that the measurement of uranium concentration was lower, as the rate of uranium concentration was 1.38ppb for the researcher, and where the

percentage of uranium concentration in males was lower than in females, and this is consistent with the results obtained.

The impact of Uranium resulting from war pollution continues for years, as the mixing of Uranium with the soil itself constitutes environmental pollution. This pollution can be observed at the same time or after years. Although there is a rapid toxic and radioactive effect of Uranium in the same location, a large part of its molecules are converted into Uranium oxides, which are spread by wind and groundwater to very long distances, up to 10 thousand km. Causes of increased Uranium concentrations in children and adults.

Table 4.10: The comparison between the concentrations of Uranium in the study samples with other regions.

Location	U. Con. ppb Healthy	U. Con. ppb Cancer Patients	Ref.
south of Iraq	0.3 - 1.59	0.83 - 2.47	[27]
Southern Iraqi	0.77-2.3	1.84 -4.51	[26]
Southern Iraqi	0.86- 2.15	1.91- 4.71	[25]
A selected region in Iraq	0.32- 1.47	0.78 - 2.47	[24]
A selected region in Iraq	1.43±0.07	2.87±0.11	[25]
A selected region in Iraq	1.38		[36]
Karbala children	0.279±0.091	0.874±0.1286	Present work
Karbala	0.335±0.095	0.8812± 0.145	Present work

4.3 Measurement of Radon Concentration in Patients with leukemia, Digestive System and Kidneys

The Radon concentration was measured in blood samples of cancer patients and the healthy group using equations (3-6), (3-7), (3-8), and (3-9) where the lowest Radon concentration was in the sample of cancer patients. It was 0.348Bq/m^3, while the highest concentration was 5.832 Bq/m^3 as in Table (4.11).

Table 4.11: The concentration of Radon in cancer patients' blood for each sample.

No	Gender	Age (y)	Living	Disease	C_{Rn}^{s}. Bq/m^3 &S.D
P1	Female	5	AL-Husseiniyah	ALL	0.779 ± 0.147
P2	Female	0.9	AL-Hindiya	ALL	3.151 ± 0.344
P3	Female	6	AL-Salam	ALL	2.096 ± 0.335
P4	Female	10	Al-Hurr	ALL	3.166 ± 0.392
P5	Female	8	Al-Amel	ALL	2.930 ± 0.479
P6	Female	11	Al Ghadeer	ALL	4.687 ± 0.395
P7	Female	5	AL-Hindiya	ALL	1.394 ± 0.143
P8	Female	7	Al-Taka	ALL	2.189 ± 0.304
P9	Female	58	AL-Hindiya	Colon	1.201 ± 0.220
P10	Female	44	Ain AL-Tamur	Colon	1.847 ± 0.172
P11	Female	80	AL-Walaa	Stomach	1.830 ± 0.197
P12	Female	72	AL-Hindiya	Stomach	2.033 ± 0.219
P13	Female	70	AL-Hindiya	Stomach	1.604 ± 0.173
P14	Female	69	AL-Taiun	Pancreas	0.815 ± 0.104
P15	Female	61	AL-Eman	Colon	0.348 ± 0.109
P16	Female	59	ALI-Amen	Stomach	2.194 ± 0.192
P17	Female	50	AL-Abassia AL-Sharqia	Colon	1.668 ± 0.181
P18	Female	60	Street AL-Najaf	Esophageal	1.069 ± 0.198
P19	Female	32	Aoun	Rectal	4.091 ± 0.427
P20	Female	30	AL-Hindiya	Rectal	3.405 ± 0.359
P21	Female	44	AL-Askary	Rectal	2.331 ± 0.294
P22	Female	61	AL-Hindiya	Rectal	2.721 ± 0.356
P23	Female	81	Al-Hurr	Esophageal	2.389 ± 0.227
P24	Male	3	Al -Zahraa	ALL	1.261 ± 0.258
P25	Male	11	Al-Wafa	ALL	1.243 ± 0.312
P26	Male	7	Al-Hurr	ALL	3.679 ± 0.381
P27	Male	7	Al-Hurr	ALL	2.216 ± 0.313
P28	Male	9	AL-Hindiya	ALL	1.936 ± 0.266
P29	Male	1.7	AL-Hindiya	ALL	1.366 ± 0.173
P30	Male	55	Al-Ghadeer	Colon	2.282 ± 0.265
P31	Male	38	AL-Askary	Colon	1.666 ± 0.153
P32	Male	48	AL-Moadafeen	Stomach	1.287 ± 0.128
P33	Male	48	AL-Moadafeen	Colon	1.931 ± 0.224
P34	Male	45	AL-Abass	Colon	3.474 ± 0.304
P35	Male	67	Al-Hurr	Pancreas	2.813 ± 0.313
P36	Male	47	AL-Askary	Colon	1.882 ± 0.127
P37	Male	73	Shohada AL-	Stomach	0.168

			Moadafeen		2.272 ±
P38	Male	44	AL-Hindiya	Colon	1.675 ± 0.250
P39	Male	64	AL-Hindiya	Colon	2.194 ± 0.238
P40	Male	59	AL-Hindiya	Colon	1.585 ± 0.263
P41	Male	64	AL-Husseiniyah	Pancreas	1.023 ± 0.190
P42	Male	35	AL-Amameen	Pancreas	0.794 ± 0.113
P43	Male	54	AL-Husseiniyah	Pancreas	1.920 ± 0.200
P44	Male	60	AL-Walaa	Colon	1.744 ± 0.223
P45	Male	75	AL-Hindiya	Colon	2.030 ± 0.220
P46	Male	50	Al-Ghadeer	Pancreas	1.163 ± 0.224
P47	Male	64	AL-Nawab	Rectal	3.945 ± 0.402
P48	Male	47	AL-Husseiniyah	Rectal	5.832 ± 0.398
P49	Male	60	AL-Taiun	Kidney	4.205 ± 0.426
P50	Male	70	Aoun	Pancreas	2.986 ± 0.357
Total No.		50			
Maximum					5.832±0.398
Minimum					0.348±0.109
Average					2.327±0.25712

Where the lowest Radon concentration was in the sample of the healthy group, it was 0.244 Bq/m^3 while the highest concentration was 2.142 Bq/m^3 as in Table (4.12).

Table 4.12: The concentration of Uranium and Radon in healthy group blood for each sample.

No	Gender	Age (y)	Living	C_{Rn}^{s}. Bq/m^3&S.D
N1	23	Female	Mulhaq-Faris	1.028 ± 0.165
N2	21	Female	AL-Atebaa	1.086 ± 0.092
N3	32	Female	AL-Husain	1.269 ± 0.152
N4	23	Female	AL-Moadafeen	1.381 ± 0.162
N5	27	Female	AL-Muealimin	0.631 ± 0.095
N6	46	Female	AL-Naqib	1.044 ± 0.159
N7	54	Female	AL-Muealimin	1.471 ± 0.199
N8	34	Female	AL-Muealimin	1.77 ± 0.164
N9	30	Female	AL-Somoud	0.651 ± 0.122
N10	21	Female	AL-Naqib	0.244 ± 0.078
N11	25	Female	AL-Husain	1.912 ± 0.223

N12	22	Female	AL-Muealimin	1.44 ± 0.188
N13	20	Female	AL-Rawdatayn	1.781 ± 0.183
N14	30	Male	AL-Hurr	0.556 ± 0.109
N15	28	Male	Friha	1.704 ± 0.153
N16	30	Male	AL-Moadafeen	0.871 ± 0.087
N17	40	Male	AL-Husain	2.142 ± 0.200
N18	24	Male	AL-Husayn	1.696 ± 0.156
N19	19	Male	AL-Rawdatayn	1.451 ± 0.148
N20	15	Male	AL- Atebaa	1.606 ± 0.19
N21	24	Male	AL- Atebaa	1.64 ± 0.172
N22	63	Male	AL-Husain	0.432 ± 0.101
N23	25	Male	AL-Muemliji	0.784 ± 0.125
N24	26	Male	AL- Atebaa	1.829 ± 0.183
N25	27	Male	AL-Waely	2.118 ± 0.206
N26	59	Male	AL-Husain	1.719 ± 0.158
N27	40	Male	AL-Husain	1.435 ± 0.132
N28	56	Male	AL-Rawdatayn	1.253 ± 0.120
N29	25	Male	Imam Ali	1.122 ± 0.111
N30	28	Male	Friha	1.682 ± 0.175
Total No.	30			
Maximum				2.142 ±0.200
Minimum				0.244 ±0.078
Average				1.324 ±0.1502

Tables (4.11) (4.12) show that the concentration of Radon gas in cancer patients is greater than in the healthy group, where the ratio of Radon concentration in the patient's group 2.327Bq/m^3 and 1.324Bq/m^3 in the healthy group. Also, the concentration of Radon in male blood samples is higher than in female blood samples, due to males being exposed to pollution at a higher rate than females due to males being exposed to a higher percentage of pollution.

Table 4.13: Relationship between gender and Radon concentration (Bq/m^3).

Gender	No	Percent	Age(y)	Minimum	Maximum	Average
Female Patients	23	46.0	0.9-81	0.348	4.687	2.171
Male Patients	27	54.0	1.7-73	.794	5.832	2.457
Total	50	100.0				
Female Healthy	13	43.3	20-54	.244	1.912	1.208
Male Healthy	17	56.7	15-63	0.432	2.142	1.414
Total	30	100.0				

Through the table (4.13), the ratio of Radon concentration in female samples of cancer patients was 2.171Bq/m^3 as for the ratio of Radon concentration in male samples 2.457Bq/m^3, and there is also a difference in the healthy group between males and females, where the concentration ratio was 1.414Bq/m^3 1.208Bq/m^3, respectively and when conducting a t-test for the independent sample, it was found that there is a difference between the Radon concentration in the healthy group and the group of cancer patients, where the value was significant $p < 0.001$. This indicates that there is a relationship between Radon concentration and the incidence of cancer, as alpha particles emitted from radon gas work to kill cells or change DNA, and this is one of the causes of cancer[40].

4.4 Conclusions

From the obtained results, we conclude the following.

1- The concentration of Uranium in the blood samples of children with leukemia was higher than in the healthy group.

2- There is a relationship between Uranium concentration and gender, where the concentration of Uranium in blood samples of female patients with leukemia was more than the concentration of Uranium in male samples due to the fact that the proportion of blood in females is 4.5 liters, while in males 5-6 liters.

3- The concentration of Uranium in children with cancer increases with increasing age, which means that age plays a role in increasing the concentration in the samples.

4- The concentration of Uranium in samples of cancer patients (digestive system and kidneys) was higher than in the healthy group.

5- The concentration of Uranium in adult males is higher than that of females because of the higher percentage of males' exposure to pollution than people due to participation in wars, working in factories and many polluted workplaces.

6- The concentration of Radon gas in samples of cancer patients was higher than the concentration of Radon in the healthy group.

7- The concentration of Radon in male samples was higher than in females.

4.5 Future Work

1- Calculate the concentration of Uranium and Radon in the areas where the concentration of Uranium was found high and study them in more detail.

2- The Uranium concentration can be calculated in other cancerous diseases.

References

[1] R. A. Meyers, *Encyclopedia of physical science and technology*. Academic, 2002.

[2] B. R. Scott, "Radiation toxicology, ionizing and nonionizing," *Encycl. Toxicol.*, vol. 4, 2014, doi: doi.org/10.1016/B978-0-12-386454-3.00057-.

[3] V. Valkovic, "Radioactivity in the Environment: Physicochemical aspects and applications," *Journal of Chemical Information and Modeling*. p. 696, 2000.

[4] D. Strominger, J. M. Hollander, and G. T. Seaborg, "Table of isotopes," *Rev. Mod. Phys.*, vol. 30, no. 2, p. 585, 1958.

[5] M. -J, Peppard D, Mason G, Gray P, "Occurrence of the (4n+ 1) series in nature," *J. Am. Chem. Soc.*, vol. 74, no. 23, pp. 6081–6084, 1952.

[6] D. C. Hoffman, F. O. Lawrence, J. L. Mewherter, and F. M. Rourke, "Detection of plutonium-244 in nature," *Nature*, vol. 234, no. 5325, pp. 132–134, 1971.

[7] G. F. Knoll, *Radiation detection and measurement*. Printed in the United States of America: John Wiley & Sons, 2010.

[8] A. Martin, S. Harbison, K. Beach, and P. Cole, *An introduction to radiation protection*. CRC Press, 2018.

[9] Sara Salih Nayif, "Measurement of Radon Concentrations in the Air Buildings for some Schools at Karbala City Using CN - 85 and LR - 115 Type II Detectors," University of Kerbala, 2019.

[10] D. Bodansky, M. A. Robkin, and D. R. Stadler, "Indoor radon and its hazards," University of Washington Press, Seattle, WA, Press, 1987.

[11] P. K. EHopke, *Radon and its decay products - occurrence, properties, and health effects*, vol. 73, no. 3. 1988.

[12] F. I. Hasan, "Indoor radon concentration measurements at Hebron University Campus: a case study," *An-Najah J. Res*, vol. . 4, 1996.

[13] S. A. Durrani and R. Ilic, *Radon Measurements By Etched Track Detectors-Applications In Radiation Protection, Earth Sciences*. World Scientific, 1997.

[14] F. G. Kondev and S. Naimi, "The AME2016 atomic mass evaluation (I). Evaluation of input data; and adjustment procedures," *Chinese Phys. C*, vol. 41, no. 3, p. 30002, 2017.

[15] L. Beach, "Exposure from the Uranium Series with Emphasis on Radon and Its Daughters, Report No. 77. National Council on Radiation Protection and Measurements: Bethesda, NCRP." Soc Nuclear Med, p. 131, 1984.

[16] A. Robertson, J. Allen, R. Laney, and A. Curnow, "The cellular and molecular carcinogenic effects of radon exposure: a review," *Int. J. Mol. Sci.*, vol. 14, no. 7, pp. 14024–14063, 2013.

[17] UNSCEAR, *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes*, vol. I. 2000.

[18] W. Popp *et al.*, "Biomarkers of genetic damage and inflammation in blood and bronchoalveolar lavage fluid among former German Uranium miners: a pilot study," *Radiat. Environ. Biophys.*, vol. 39, no. 4, pp. 275–282, 2000.

[19] Instituto de Protección Radiológica de Irlanda and Registro Nacional de Cáncer de Irlanda, "Health Risks due to Exposure to Radon in Homes in Ireland," no. September, 2005.

[20] A. Vaiserman, A. Koliada, O. Zabuga, and Y. Socol, "Health Impacts of Low-Dose Ionizing Radiation: Current Scientific Debates and Regulatory Issues," *Dose-Response*, vol. 16, no. 3, 2018, doi: 10.1177/1559325818796331.

[21] S. E. Wagner *et al.*, "Hypertension and hematologic parameters in a community near a

Uranium processing facility," *Environ. Res.*, vol. 110, no. 8, pp. 786–797, 2010.
[22] M. A. S. Weam Saad Al-Hamadany, Dhuha S. Saleh, "Radiation Pollution in Cancer and other Diseases Using some Immunological and Clinical Parameters," *Iraqi J. Vet. Med.*, vol. 36, pp. 33–40, 2012.
[23] N. F. Tawfiq, L. T. Ali, and H. A. Al-Jobouri, "Uranium concentration measurements in human blood for some governorates in Iraq using CR-39 track detector," *J. Radioanal. Nucl. Chem.*, vol. 295, no. 1, pp. 671–674, 2013, doi: 10.1007/s10967-012-2114-2.
[24] N. F. S. Anees A. AL-Hamzawi, M. S. Jaafar, Nada F. Tawfiq, "Uranium Concentration in Human Blood using Fission Track Etch Technique," *J. Nat. Sci. Res.*, vol. 3, no. 13, pp. 176–182, 2013.
[25] A. A. Al-Hamzawi, M. S. Jaafar, and N. F. Tawfiq, "Uranium concentration in blood samples of Southern Iraqi leukemia patients using CR-39 track detector," *J. Radioanal. Nucl. Chem.*, vol. 299, no. 3, pp. 1267–1272, 2014, doi: 10.1007/s10967-013-2808-0.
[26] A. A. Al-Hamzawi, M. S. Jafaar, and N. F. Tawfiq, "The Relationship between Uranium Contamination and Cancerous Diseases of Southern Iraqi," *Pensee J.*, vol. 76, no. 3, p. 36, 2014, [Online]. Available: https://www.researchgate.net/publication/315761970.
[27] A. A. Al-Hamzawi, M. S. Jaafar, and N. F. Tawfiq, "The measurements of Uranium concentration in human blood in selected regions in Iraq using CR-39 track detector," *Adv. Mater. Res.*, vol. 925, no. April, pp. 679–683, 2014, doi: 10.4028/www.scientific.net/AMR.925.679.
[28] N. F. Salih, Z. M. Jafri, and M. S. Aswood, "Measurement of radon concentration in blood and urine samples collected from female cancer patients using RAD7," *J. Radiat. Res. Appl. Sci.*, vol. 9, no. 3, pp. 332–336, 2016, doi: 10.1016/j.jrras.2016.02.002.
[29] K. P. Messier and M. L. Serre, "Lung and stomach cancer associations with groundwater radon in North Carolina, USA," *Int. J. Epidemiol.*, vol. 46, no. 2, pp. 676–685, 2017, doi: 10.1093/ije/dyw128.
[30] A. A. Battawy, A. S. Jasim, and H. Deaf-allah, "Finding Risk and Radiological Exposure Factor for Iraqi Workers in Selected Regions in the Center and North of Iraq," no. September 2017.
[31] E. M. Rasheed, "Measured the concentrations of Uranium in human blood samples from Iraq using CN-85 nuclear track detector _ المجلة العربية للعلوم و نشر الأبحاث - AJSRP." Department of physics || College of Sciences || Al-Nahrain University || Baghdad || Iraq, 2018.
[32] A. B. Hassan, A. A. H. Mohsen, H. A. A. Mraity, and A. A. Abojassim, "Determination of alpha particles levels in blood samples of cancer patients at Karbala Governorate, Iraq," *Iran. J. Med. Phys.*, vol. 16, no. 1, pp. 41–47, 2019, doi: 10.22038/ijmp.2018.32376.1383.
[33] M. M. Abed, K. H. Mahdi, and W. S. Al-, "Estimation of Uranium concentration in blood samples of kidneys failure patients in Al-Muthanna governorate Estimation of Uranium Concentration in Blood Samples of Kidneys Failure Patients in Al-Muthanna Governorate," *AIP Conf. Proc. 2123*, no. July 2019.
[34] Ansam F. Showard and Murtadha Sh. Aswood, "Measuring of Alpha particles in Blood samples of Leukemia patients in Babylon governorate, Iraq," *IOP Conf. Ser. J. Phys. Conf. Ser. 1234 012062*, doi: 10.1088/1742-6596/1234/1/012062.
[35] A. F. Showard and M. S. Aswood, "Effect of gender and occupations on Uranium concentration in human blood and soil samples collected from Babylon, Iraq," *Polish J. Med. Phys. Eng.*, vol. 26, no. 3, pp. 143–148, 2020, doi: 10.2478/pjmpe-2020-0016.
[36] I. H. Kadhim, A. A. Shakir, M. Madani, and M. A. K. Hadi, "Uranium Concentration

Measurements of Human Blood Samples Using CR-39," *Biochem. Cell. Arch*, vol. 20, no. No. 2, pp. 5497–5500, p. 4, 2020.
[37] D. M. A. Stojsavljević, V.V.Avdin, D.A. Zherebtsov, "URANIUM CONCENTRATIONS IN TISSUES AND OTHER CLINICAL SAMPLES OF THE SERBIAN POPULATION," pp. 97–104, 2021, doi: 10.14529/chem210110.
[38] S. Muhammad, E. S. Ali, and M. M. Asker, "Determination Radon Concentration (Radon Gas) in Urine of Patients with Cancer." 2021, doi: 10.14704/nq.2021.19.4.NQ21041.
[39] A. A. Aziz, F. M.Majed, and Nada F. Tawfiq, "Evaluation of Uranium Concentration in the Blood of Cancer Patients in Salah Al-Din Governorate," *Tikrit J. Pure Sci.*, vol. 26, pp. 94–97, 2021.
[40] E. E. Fontes, *RADIAÇÃO,Efeitos e fontes*, 2016th ed. 2016.
[41] R. C. Manual, "Biological Effects of Radiation," *Phys. Today*, vol. 9, no. 7, pp. 34–35, 1956, doi: 10.1063/1.3060037.
[42] F. G. Becker *et al.*, *Ganongs Review of Medical Physiology*, vol. 7, no. 1. 2015.
[43] C. Grupen, "Units of Radiation Protection," no. March, pp. 4–18, 2010, doi: 10.1007/978-3-642-02586-0_2.
[44] U. N. S. C. on the E. of A. Radiation, "Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1993 Report." p. 918, doi: doi.org/10.18356/2c4203dc-en.
[45] W. Burkart, P. R. Danesi, and J. H. Hendry, "Properties, use and health effects of depleted Uranium," *Int. Congr. Ser.*, vol. 1276, pp. 133–136, 2005, doi: 10.1016/j.ics.2004.09.047.
[46] R. L. Kathren, "The Health Hazards of Depleted Uranium Munitions Part I," *J. Radiol. Prot.*, vol. 21, no. 3, pp. 331–332, 2001, doi: 10.1088/0952-4746/21/3/701.
[47] A. Army Environmental Policy Institute, "HEALTH AND ENVIRONMENTAL CONSEQUENCES OF DEPLETED URANIUM USE IN THE UArmy Environmental Policy Institute, AEPI." pp. 23–27, 1995.
[48] S. Keith, H. E. Murray, and W. Spoo, "Toxicological profile for ionizing radiation," 1999.
[49] I. M. Fisenne, P. M. Perry, K. M. Decker, and H. W. Keller, "The daily intake of 234,235,238 U, 228,230,232 Th and 226,228 Ra by New York City residents.," *Health Phys.*, vol. 53, no. 4, pp. 357–363, 1987.
[50] N. D. Priest, "Toxicity of depleted Uranium ," *Lancet*, vol. 357, no. 9252, pp. 244–246, 2001.
[51] R. J. Fellows, C. C. Ainsworth, C. J. Driver, and D. A. Cataldo, "Dynamics and transformations of radionuclides in soils and ecosystem health," *Soil Chem. Ecosyst. Heal.*, vol. 52, pp. 85–132, 1998.
[52] E. Schnug, H. Steckel, and S. Haneklaus, "Institute of Plant Nutrition and Soil Science," 2005.
[53] A. Bleise, P. R. Danesi, and W. Burkart, "Properties, use and health effects of depleted Uranium (DU): a general overview," *J. Environ. Radioact.*, vol. 64, no. 2–3, pp. 93–112, 2003.
[54] A. Rump, S. Eder, A. Lamkowski, C. Hermann, M. Abend, and M. Port, "A quantitative comparison of the chemo- and radiotoxicity of Uranium at different enrichment grades," *Toxicol. Lett.*, vol. 313, no. April, pp. 159–168, 2019, doi: 10.1016/j.toxlet.2019.07.004.
[55] D. Ed. Jl. Y, "Thermal annealing of iron tracks in muscovite, labradorite and olivineDartyge, E Duraud, J P Langevin, Y," *Radiat. Eff.*, vol. 34, no. 1–3, pp. 77–79, 1977.

[56] S. A. Durrani and R. K. Bull, *Solid state nuclear track detection: principles, methods and applications*, vol. 111. Elsevier, 2013.
[57] E. Dartyge, J. P. Duraud, Y. Langevin, and M. Maurette, "A new method for investigating the past activity of ancient solar flare cosmic rays over a time scale of a few billion years," in *Lunar and Planetary Science Conference Proceedings*, 1978, vol. 9, pp. 2375–2398.
[58] P. B. Price, D. Lal, A. S. Tamhane, and V. P. Perelygin, "Characteristics of tracks of ions of $14 \leqslant Z \leqslant 36$ in common rock silicates," *Earth Planet. Sci. Lett.*, vol. 19, no. 3, pp. 377–395, 1973.
[59] R. L. Fleischer and P. B. Price, "Tracks of charged particles in high polymers," *Science (80-.).*, vol. 140, no. 3572, pp. 1221–1222, 1963.
[60] E. M. SYMES, "PB PRICE EM SYMES," *J. Appl. Phys*, vol. 34, p. 2903, 1963.
[61] P. B. Price and R. M. Walker, "A new track detector for heavy particle studies," *Phys. Lett.*, vol. 3, no. 3, pp. 113–115, 1962.
[62] P. B. Price and R. M. Walker, "Electron microscope observation of etched tracks from spallation recoils in mica," *Phys. Rev. Lett.*, vol. 8, no. 5, p. 217, 1962.
[63] M. Y. Rajab, "Digital Processing and Analysis for the Tracks Produced From the Irradiation with Neutrons Source 241 Am-9 Be on Some of Solid State Nuclear Track Detectors."
[64] S. A. Durrani, N. A. Karamdoust, and I. J. M. Al-Khalifa, "The Effect of the registration temperature on the response of CR-39 to alpha particles and fission fragments," *Radiat. Prot. Dosimetry*, vol. 34, no. 1–4, pp. 43–46, 1990.
[65] A. M. Al-Wasity, "A study of concentration measurement of alpha and gamma emitting radionuclides in soil of Wasit governorate." M. Sc. Thesis, University of Baghdad, Iraq, 2010.
[66] A. A. Mohammed, "Concentration measurements of radon, Uranium and background of gamma rays in air at the university of Baghdad–Al-Jadiriyah site," *Univ. Baghdad, Ms. c thesis*, vol. 46, 2013.
[67] A. M. Bhagwat, "Solid state nuclear track detection: Theory and applications," Indian Society for Radiation Physics, 1993.
[68] R. L. Fleischer, P. B. Price, R. M. Walker, and R. M. Walker, *Nuclear tracks in solids: principles and applications*. Univ of California Press, 1975.
[69] H. A. Khan and N. A. Khan, "Solid State Nuclear Track Detection (SSNTD): A Useful Scientific Tool for Basic and Applied Research," *Med. J. Islam. World Acad. Sci.*, vol. 2, no. 4, pp. 303–312, 1989.
[70] B. G. Cartwright, E. K. Shirk, and P. B. Price, "A nuclear-track-recording polymer of unique sensitivity and resolution," *Nucl. Instruments Methods*, vol. 153, no. 2–3, pp. 457–460, 1978.
[71] J. R. Harvey, R. J. Tanner, W. G. Alberts, D. T. Bartlett, E. K. A. Piesch, and H. Schraube, "The contribution of Eurados and Cendos to track etch neutron dosimetry: the current status in Europe," *Radiat. Prot. Dosimetry*, vol. 77, no. 4, pp. 267–304, 1998.
[72] A. Q. M. Al-Rubyie, "Radioactive detection on the blood samples of cancer patients diseases by using CR-39 detector and its effect on cytogenetic," *Ms. c thesis), AL-Nahrain Univ.*, 2004.
[73] S. A. Durani and R. K. Bull, "Solid State Nuclear Detection." Pergamon Press Oxford, 1987.
[74] D. Xiao-Jiao *et al.*, "Calibration of solid state nuclear track detector CR-39 with monoenergetic protons," *Acta Phys. Sin.*, vol. 59, no. 5, pp. 3147–3153, 2010.
[75] F. H. Taha, "Radiation dose assessment for ionizing and ultraviolet radiations using

CR-39, Lexan and LR-115 nuclear track detectors," *AL-Nahrain Univ. Ms. c thesis*, vol. 23, 2011.
[76] C. R. Peeples, "Alternatives to the Americium-beryllium Neutron Source for the Compensated Neutron Porosity Log," University in partial fulfillmen, 2007.
[77] A. A. Al-Hamzawi, M. S. Jaafar, and N. F. Tawfiq, "Concentration of Uranium in human cancerous tissues of Southern Iraqi patients using fission track analysis," *J. Radioanal. Nucl. Chem.*, vol. 303, no. 3, pp. 1703–1709, 2015.
[78] S.-L. Guo, B.-L. Chen, and S. A. Durrani, "Solid-state nuclear track detectors," in *Handbook of radioactivity analysis*, Elsevier, 2020, pp. 307–407.
[79] S. Guo, "Principles, techniques and applications of solid state nuclear track detectors," 1988.
[80] L. Tommasino, "Solid state nuclear track detection: Principles, methods and applications: 317 pp.; 116 illus.; 644 r Pergamon Press, Oxford." Pergamon, 1987.
[81] H. A. Khan and S. A. Durrani, "Efficiency calibration of solid state nuclear track detectors," *Nucl. Instruments Methods*, vol. 98, no. 2, pp. 229–236, 1972.
[82] M. M. Abed, "Calculation of Uranium concentration in blood and urine samples of patients with renal insufficiency in Muthanna Governorate," *Ph.D. Thesis. Univ. Baghdad.*, p. 115, 2019.
[83] OCHA, "Kerbala Governorate Profile," no. April 2015.
[84] M. S. Al-Nafiey, M. S. Jaafar, S. Bin Bauk, and N. F. Salih, "Design and fabrication of new radon chamber for radon calibration factor of measurement," *Int. J. Sci. Eng. Res.*, vol. 3, no. 10, pp. 1–6, 2012.
[85] Y. S. Mayya, K. P. Eappen, and K. S. V Nambi, "Methodology for mixed field inhalation dosimetry in monazite areas using a twin-cup dosemeter with three track detectors," *Radiat. Prot. Dosimetry*, vol. 77, no. 3, pp. 177–184, 1998.
[86] R. Barillon, D. Klein, A. Chambaudet, and C. Devillard, "Comparison of effectiveness of three radon detectors (LR115, CR39 and silicon diode pin) placed in a cylindrical device-theory and experimental techniques," *Nucl. Tracks Radiat. Meas.*, vol. 22, no. 1–4, pp. 281–282, 1993.
[87] Elzain A. Abd-Elmoniem, "Measurement of Radon-222 concentration levels in water samples in Sudan," *Adv. Appl. Sci. Res.*, vol. 5, no. 2, pp. 229–234, 2014.
[88] G. H. W. and F. H. Arfken, *Mathematical Methods for Physicist Seventh Edition*. 2013.
[89] R. L. Fleischer and P. B. Price, "Charged particle tracks in glass," *J. Appl. Phys.*, vol. 34, no. 9, pp. 2903–2904, 1963, doi: 10.1063/1.1729828.
[90] A. C. Miller, M. Stewart, K. Brooks, L. Shi, and N. Page, "Depleted Uranium - catalyzed oxidative DNA damage: absence of significant alpha particle decay," *J. Inorg. Biochem.*, vol. 91, no. 1, pp. 246–252, 2002.
[91] S. L. Koul and L. T. Chadderton, "Uranium in blood," *Radiat. Eff.*, vol. 50, no. 1, pp. 19–21, 1980.
[92] L. Al-Tememy, "Uranium Concentration Measurements of Human Blood Samples Using CR-39," *A Thesis ,College Sci. Al-Nahrain Univ.*, 2007.
[93] E. I. Hamilton, "Uranium content of normal blood," *Nature*, vol. 227, no. 5257, pp. 501–502, 1970.

الخلاصة

في هذه الدراسة ، تم قياس تركيز اليورانيوم والرادون في عينات الدم لمرضى السرطان (اللوكيميا والجهاز الهضمي والكلى) باستخدام تقنية كاشف الأثر النووي ذوالحالة الصلبة CR-39 ، بسمك من 500 ميكرومتر ومساحة(1× 1) سم^2. تم جمع 115 عينة من مختلف الأعمار لفحصها تتضمن 75 عينة من مرضى السرطان و 40 عينة من المجموعة الضابطة. أخذت العينات من مستشفى مدينة الحسين الطبية في محافظة كربلاء) . تم قياس تركيز اليورانيوم في 30 عينة للأطفال 25 مريضاً بسرطان الدم و 5 من مجموعة التحكم ، حيث كان أعلى معدل لتركيز اليورانيوم في مجموعة مرضى اللوكيميا لدى الأطفال 0.874 جزء في البليون مقارنة بمجموعة التحكم عند 0.279 جزء في البليون. وشمل الجزء الآخر من الدراسة قياس تركيز اليورانيوم في 60 عينة ، وهي 50 مريضا بالسرطان في الجهاز الهضمي والكلى ، و 10 في المجموعة الضابطة ، حيث كان أعلى معدل لتركيز اليورانيوم في مجموعة مرضى السرطان عند 0.8812. جزء في البليون ومجموعة التحكم 0.381 جزء في البليون. ونتيجة لهذه التراكيز نقول أن هناك علاقة بين تركيز اليورانيوم والجنس والعمر ، كما أن معدل تركيز اليورانيوم عند الإناث أعلى منه عند الذكور. كما أن تركيز اليورانيوم عند الإناث والذكور يزداد مع تقدم عمر المريض.

حيث كان أعلى تركيز لليورانيوم في مجموعة مرضى اللوكيميا لدى الأطفال 1.874 جزء في البليون مقارنة بالمجموعة الصحية عند 0.33 جزء في البليون. كان متوسط تركيز اليورانيوم للمجموعة الصحية والمرضى 0.279 جزء في البليون و 0.874 جزء في البليون على التوالي ، وشمل الجزء الآخر من الدراسة قياس تركيز اليورانيوم في 60 عينة ، و 50 مريضًا بالسرطان مع الجهاز الهضمي والكلى ، و 10 في المجموعة السليمة ، حيث كان أعلى تركيز لليورانيوم في مجموعة مرضى السرطان عند 2.164 جزء في البليون والمجموعة الصحية 0.614 جزء في البليون. كان متوسط تركيز اليورانيوم للمجموعة الصحية والمرضى 0.335 جزء في البليون 0.8812 جزء في البليون و على التوالي نتيجة لهذه التركيزات ، هناك علاقة بين تركيز اليورانيوم والجنس والعمر ، وكذلك كانت نسبة تركيز اليورانيوم في الإناث أعلى من للذكور. يزداد تركيز اليورانيوم في الإناث والذكور مع تقدم عمر المريض

تم قياس تركيز الرادون في 80 عينة من الدم و 50 عينة من مرضى السرطان و 30 عينة من المجموعة الصحية. تم تخزين العينات لمدة 60 يومًا في أنابيب. تم استخدام كاشف الأثر النووي CR-39 بأبعاد (2.5×2.5) سم^2 لقياس مسار جسيمات ألفا. يتراوح معدل تركيز الرادون الموجود في عينات مرضى السرطان ما بين (5.832 - 0.348) بكرل لكل مترمكعب ومعدل تركيز الرادون في المجموعة الصحية (2.142 - 0.244) بكرل لكل مترمكعب. كما وجدنا أن تركيز غاز الرادون عند الذكور أعلى نسبيًا منه عند الإناث ويرجع ذلك إلى أن نسبة التلوث التي يتعرض لها الذكور أعلى من نسبة الإناث.

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تحديد تراكيز اليورانيوم والرادون في عينات دم مختارة لمحافظة كربلاء

رسالة

مقدمة الى مجلس كلية العلوم /جامعة كربلاء

كجزءمن متطلبات نيل درجة الماجستير في علوم الفيزياء

من قبل

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باشراف

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