Abstract

The aim of this project is to determine the concentrations of uranium concentration in human blood in some governorates of Iraq for (workers in radiation field in ministry of science and technology and non occupational workers in radiation field) and to find the relationship between the uranium concentration with the number of working years and with the type of human gender.

The nuclear reaction used as source of nuclear fission fragment is U-235 (n,f), obtain by the bombardment of U-235 with thermal neutrons from (Am- Be) source which has a flux of (5×10^{3} $n.cm^{-2}$ $.s^{-1}$).

The results show that the maximum uranium concentration in blood of workers in the radiation field (1.99 ppb) (male, 36 years old and 12 years working in the radiation field and living in Basrah governorate) and the minimum concentration (0.095 ppb) (male, 22 years old and 1 year working in radiation field and living in Baghdad governorate). While for non occupational workers the maximum of uranium concentration (1.84 ppb) (female, 63 years old and living in Al- Muthana governorate) and the minimum concentration (0.25 ppb) (male, 38 years old and living in Al-Ramadi governorate).

Finally, it has been found that the uranium concentration in blood samples of workers in radiation field are higher than those of non occupational workers.

الخلاصة

يتضمن البحث دراسة عملية لأيجاد تركيز اليورانيوم في الدم البشري في بعض محافظات العراق (العاملين في مجال الاشعاع في وزارة العلوم والتكنلوجيا و الغير العاملين في مجال الاشعاع) وايجاد العلاقة بين تركيز اليورانيوم وعدد سنوات العمل في مجال الاشعاع ونوع الجنس البشري.

وقد استخدمت تقنية عد اثار شظايا الانشطار النووي الناتجة من انشطار نواة اليورانيوم U-235 المقصوفة بالنيوترونات الحرارية من المصدر النيتروني (Am-Be) بفيض نيتروني (5×10^{3} $n.cm^{-2}.s^{-1}$) وتم تحديد التراكيز بالحسابات المعتمدة على المقارنة مع النماذج القياسية .

وقد اوضحت النتائج بأن اعلى تركيز لليورانيوم في نماذج الدم للاشخاص العاملين في مجال الاشعاع (1.99 ppb) (ذكر، ١٢ سنة خدمة في مجال الاشعاع ويسكن في محافظة البصرة) واقل تركيز (0.095 ppb) (ذكر ، سنة واحدة خدمة في مجال الاشعاع ويسكن في محافظة بغداد)

اما بالنسبة لغير العاملين في مجالالاشعاع فأن اعلى تركيز (1.89 ppb) (انثى، في محافظة المثنى) واقل تركيز (0.25 ppb) (ذكر قي محافظة الرمادي) وكذلك اوضحت النتائج بأن اعلى تركيز لليورانيوم كان للاشخاص العاملين في مجال الاشعاع.

Republic of Iraq
Ministry of Higher Education
And Scientific Research
AL-Nahrain University
College of Science

Uranium Concentration Measurements of Human Blood Samples Using CR-39

A Thesis
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in partial fulfillment of the requirements for
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Physics

By

Lamya' Tawfiq Ali Al-Tememy

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جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة النهرين/ كلية العلوم

قياس تراكيز اليورانيوم في الدم البشري باستخدام CR-39

رسالة
مقدمة الى كلية العلوم في جامعة النهرين
كجزء من متطلبات نيل شهادة ماجستير علوم في الفيزياء
من قبل

لمياء توفيق علي التميمي
(بكالوريوس ٢٠٠٤)

ربيع الأول ١٤٢٨ هـ
نيسان 2007 م

1.1 Composition of Blood

Blood is the distributing agent in the body [1]. The function of the blood is to deliver nutrients, hormones and oxygen to tissues, collect and dispose of the wastes from cellular metabolism, deliver specialized cells to tissues for protection agent the external environment, and prevent leakage by closing holes in blood vessels [2].

Blood is consists of cells surrounded by a liquid matrix, which circulates through the heart and blood vessels. Total blood volume in females is (4-5) litter, males is (5-6) litter, cells and cells fragments it is about 55% [3]. All blood cells develop from stem or precursor cells that are produced principally in the bone marrow [4], as shown in figure (1.1) [1].

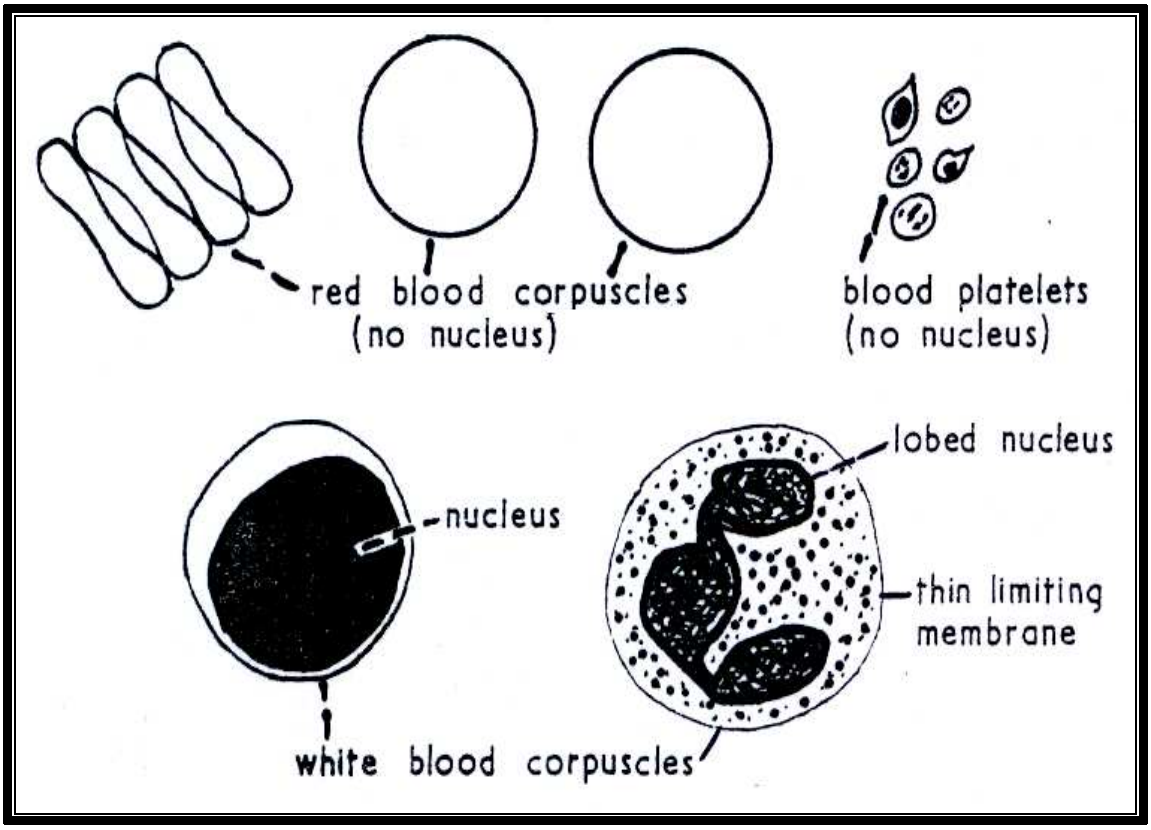


Figure (1-1):- Blood cells under the microscope (2000x)[1].

1.1.1 White Blood Cells

It colorless nucleated cells whose primary function is protection against invading organisms [2]. They help to defend the body against infectious diseases and foreign materials as part of the immune system [1].

White blood cells include several different types

- Neutrophils (Granulocytes or Polys)
- Monocytes
- Lymphocytes

Each one has its own role in protecting body from germs. Neutrophils kill most bacteria. Monocytes kill germs such as tuberculosis. Lymphocytes are responsible for killing viruses and for overall management of the immune system. When lymphocytes see foreign material, they increase the body's resistance to infection. White blood cells play a major role in fighting infection, white blood cells occupy less than 1% of the total blood volume [5].

1.1.2 Red Blood Cells

Red blood cells are disk-shaped and biconcave. Because the cell does not have a nucleus, its life span is limited (120 days), by its energy supply [2]. The diameter of the cell (8.4µm) and its thickness (4.2µm), the cell contains 71% water, 28% dye, 0.7% greases, 0.3% different composition [6,7]. The name of the red blood reflects the bright red color of the cell. Red blood cells are responsible for carrying oxygen and carbon dioxide throughout the human. The percentage of red blood cells in the blood is called the hematocrit. The part of red blood cells that carries oxygen is a protein called hemoglobin. All body tissues need oxygen to work properly. When the bone marrow is working normally, the red blood cells count remains stable. Anemia occurs when there

are too few red blood cells in the body. Symptoms of anemia include shortness of breath, weakness and fatigue [5].

1.1.3 Platelets:

Platelets are small fragments of cells (megakaryocytes), which are produced in bone marrow and contain enzymes and other biologically active substances (mediator). Platelets are the cells that help control bleeding [8].

1.1.4 Plasma:

Plasma is pale yellow fluid that consists of about 91% water and 9% other substances (electrolytics and proteins). Plasma is colloidal solution, which is a liquid containing suspended substances that not settle out of solution [2].

1.1.5 Serum:

Serum is clear fluid that separates from the blood upon coagulation, when all cellular elements are removed [2].

1.1.6 Hemoglobin:

The red cells contains iron-containing pigment called hemoglobin, whose primary function is to store and transport oxygen [4]. Hemoglobin is usually measured in grams per deciliter (g/dl) or grams per milliliter (g/100 ml) of blood . In adult males, a typical level would be approximately 14 g/dl and in adult females 13 g/dl .

1.2 The Effects Radiation on The Composition of Blood

The effect of radiation on lymph cells and platelets is fast, but it is faster than in the grains cells. The change of composition of blood in the body appears on the damage from as the following [9]:

1. Anemia, which is a lack of red blood cells and produces fatigue.
2. Fatigue, which occurs when the cells do not receive enough oxygen, because there are not enough cells to carry oxygen.
3. Susceptibility to infection, because there are not enough white blood cells to fight bacteria, viruses, and other microbes.
4. Bleeding, this can occur when there are not enough platelets to help with blood clotting.
5. Leukemia, which occurs because increasing number of immature white blood cells.

1.3 Leukemia

1.3.1 Definition of Leukemia

Leukemia is cancer that starts in the organs that make blood, namely the bone marrow (the soft inner part of the bone) and the lymph system. In leukemia, abnormal and immature white blood cells are produced the bone marrow and lymph system. The immature white blood cells are called leukocytes.

In some individuals, leukocytes are so numerous that the blood actually has a whitish tinge. When abnormal and immature white blood cells are produced, production of normal cells decreases and the ability to fight infection decreases [10].

1.3.2 Causes of Leukemia

The specific cause of leukemia is still not known, scientists suspect that viral, genetic, environment immunologic factors may be involved. Some viruses cause leukemia in animal. But in humans viruses cause only one rate type of leukemia even if a virus is involved, leukemia is not contagious. It can not spread from one person to another. There may be a genetic predisposition to leukemia. There are rare families where people born with chromosome damage may have genes that increase their chances of developing leukemia. Environmental factors, are play a role some cases, such as high-dose radiation and exposure to certain toxic chemicals, have been directly linked to leukemia. People with immune-system deficiencies appear to be at greater risk for cancer because of the body s decreased ability to resist foreign cells. All of these factors may explain why a small number of people develop leukemia. But, among most people, the cause of leukemia is not known [5].

1.3.3 Classification of Leukemia

Leukemia is split in to the acute and chronic forms. Furthermore, the diseases are classified according to the type of abnormal cell found most in the blood (lymphoid cell or myeloid). When leukemia affects lymphoid cells, it is called lymphocytic leukemia. When myeloid cells are affected, the disease is called myeloid or myelogenous leukemia.

The four main forms are [11].

- Acute lymphocytic leukemia (ALL) is the most common type of leukemia in young children. This disease also affects adults, especially those age 65 year and older.
- Acute myelocytic leukemia (AML) occurs in both adults and children, This type of leukemia is sometimes called acute nonlymphocytic leukemia (ANLL).

- Chronic lymphocytic leukemia (CLL) most often affects adults over the age of 55 year. It sometimes occurs in younger adults, but it almost never affects children.
- Chronic myelocytic leukemia (CML) occurs mainly in adults. Avery small number of children also develop this disease.

The most common forms in adults are AML and CLL, whereas in children ALL is more prevalent.

1.4 Previous Studies

Many studies have been performed to investigate and measure the concentration of radioactive elements in biological samples (tissues, bone, blood, etc.) by using different techniques, some of these studies are abstracted as follows:

- Pricer M., 1968 [12] measured the uranium concentrations in human blood by using neutron activation analysis. The result of analysis of uranium contents was (5×10^{-10} g/mol).
- Hamilton E.I., 1970 [13] determined the concentrations of uranium in blood by using the delayed neutrons detection technique, where the average concentration was (0.84 ppb).
- Cheek C.H. & Carpenter B.S., 1970 [14] determined the uranium concentration in blood and plasma by neutron activation analysis technique. The results were (0.56 - 0.86 ppb) in blood and (1.2 - 6.5 ppb) in plasma.
- Koul S.L. & Chadderton L.T., 1979 [15] measured the concentrations of uranium in whole blood and plasma for healthy people and other injured by leukemia using the track etch technique. The concentrations for healthy people ranged between (0.35-0.6 ppb) in whole blood, and (0.11 - 0.82 ppb) in plasma, where the concentrations ranged between (1.5 – 8.7 ppb) in whole blood, and (12 - 180 ppb) in plasma.

- Nagpaul K.K. & Parshah R.N., 1979 [16] determine the concentrations of uranium in human blood by using track etch technique, where the concentrations ranged between (0.89 - 1.79 ppb).
- Romero M., Sanchez M. & Segovia N., 1984 [17] made a study in blood and plasma by using track etch technique, they were obtained uranium concentration (1.4-1.5 ppb) in blood and (0.96- 1.6 ppb) in plasma.
- Gaswami T.D. & Das K.C., 1986 [18] were studies the uranium concentrations in human blood by using track etch technique, the result were approximately (0.33 - 0.74 ppb).
- Segovia N., Olguin M.E. & Romero M., 1986 [19] made a study to determine the concentrations of uranium in whole blood and plasma samples from a group of radiation exposed workers and another of leukemia patients by using the track etch technique. The mean uranium concentration for the worker population was (0.98 ppb) in whole blood and (1.04 ppb) in plasma. For leukemia patients, the mean uranium concentration was (1.71 ppb) in whole blood and (1.79 ppb) in plasma.
- Al-Timimi W.K. M., 2000 [20] measured the concentrations of depleted uranium in the human blood and tissues by using CR-39 nuclear track detector. The concentrations ranged between (0.041 – 0.073 ppm) in the blood and (0.039 – 0.046 ppm) in the tissues.
- Sultan M.F., 2001 [21] measured uranium concentrations in injured human blood by using induced fission track technique. The result was (0.066 - 0.2 ppm).
- Al-Gailani A.W., 2003 [22] made a study on human blood to determine the concentration of depleted uranium by using CR-39 nuclear track detector. The concentration of depleted uranium was (0.03 - 0.114 Bq /mol) in lymph cells.
- Ibraheem M.F., 2003 [23] determine the concentrations of depleted uranium in injured human tissues by using CR-39 nuclear track detector,

where the concentrations obtained ranged between (0.031- 0.6 ppm) and the average concentration was (0.044 ppm).

- Hassan S.F., 2006 [24] measured the uranium concentration in injured human blood for some governorates of Iraq (Baghdad, Basrah and Al-Ramadi) by using CR-39 nuclear track detector. The results were (0.073-0.22 ppm) in Baghdad, (0.965-1.992 ppm) in Basrah and (0.835-1.174 ppm) in Al-Ramadi.

1.5 The Aim of The Present Work

The purpose of the present work is to determine the uranium concentration in blood of the workers and non workers in the field of radiation and to study the relationship between the uranium concentration in the blood and the number of working years.

3.1 History of Solid State Nuclear Track Detectors

The solid state nuclear track detectors (SSNTDs) can be defined as those material, when exposed to a certain dose of radiation one or more than one measurable parameters will change. The passage of heavy ionizing nuclear particles through most insulating solids creates narrow paths of intense damages on an atomic scale. These damage "tracks" can be revealed and made visible either directly by using Transmission Electron Microscopy (TEM) or indirectly by chemical etching and using an ordinary optical microscope [74].

The idea of solid state nuclear track detector began in 1958, when Young working at the atomic energy research establishment at Harwell in England, observed that lithum fluoride (LiF) crystal held in contact with uranium foil irradiated with thermal neutrons, a number of pits (damage regions) were revealed after treating the bombarded crystal with chemical reagent[73]. The number of these pits showed a complete correspondence with estimated fission fragment which have recoiled into the crystal from the uranium foil. In 1959, Silk and Barnes working in the same establishment had recorded direct observations of damage regions, as hair-like tracks, in mica [75], they were the first to be observed on a Transmission Electron Microscope (TEM). Then, in a very short period of time a number of experiments were performed which led to the discovery of etching technique and the optimum conditions of etching. These experiments led Fleischer, Price and Walker working together at the General Electric Research Laboratories (GERL) at schenectady, New York to extend the etching technique of Young (his work was unknown to them at that time)[73]. They repeated and developed the observations published by Silk and Barnes [75] by introducing fission fragment and other heavily charged particles in many solid where they observed the tracks directly using an electron microscope [76,77]. They also showed that the fission fragments in mica can be revealed by etching with a selective chemical agent of hydrogen fluride (HF) to observe the latent tracks with an optical

microscope [78,79]. The successive studies of etchable tracks observation led the team (Fleischer, Price and Walker) to a fact that the nuclear track registration and etching are a general phenomena in all dielectrics [80]. According to this fact, they introduced a new nuclear track detectors termed as solid state nuclear track detectors (SSNTDs).

After the publication of the first review article by Fleischer, and his Co-authors Price and Walker published their report on the application of SSNTDs in nuclear science and geophysics [81]. In this respect, the solid state nuclear track registration technique caught the attention of scientists in different laboratories and universities all over the world and led to the present wide spread application of SSNTDs.

Since 1960, solid state nuclear track detectors have been widely used for nuclear track registration. Many types of these detectors which have been introduced are grouped in to two categories one is the inorganic detectors such as mica, glass, etc. and the other is the organic detectors (plastic) including CN-85, LR-115, CR-39, Lexan, Mikrofol, etc. The particle properties of the detectors such as availability, ease of use and low cost led to its rapid application in a wide variety of fields of science and technology, mostly in nuclear and particle physics, nuclear dosimetry, cosmic rays, etc. Moreover, these also are used in other fields such as geophysics, astrophysics, plasma physics, medicine, biological science and radiography. Significant nuclear physics experiments began to be carried out in an increasing speed after the discovery of track detectors. The SSNTDs have become an important tool in the investigation of uranium exploration and in the detection of radon gas environmentally. The increased importance of SSNTDs and their wide application rendered them necessary to study the tracks structure formation, their properties and the extreme influence of environmental parameters on them.

3.2 Solid State Nuclear Track Detectors

Solid state nuclear track detectors (SSNTDs) are insulating materials have the capabilities for measuring concentration and spatial distribution of isotopes if they emit heavy charge particles, either directly or as a result of specific nuclear reactions [82].

The damage of these particles along their path is called track (Latent track), may become visible under an ordinary optical microscope after etching with suitable chemicals [83]. The damage track detectors can be considered to be the converse of scintillation, since, in this case the quantity of importance is the energy left near the particle trajectory, which determines the chemical track reactivity [82].

There are two types of solid state nuclear track detectors:-

3.2.1 Inorganic Detectors

Inorganic detectors are compounds where Carbon and Hydrogen do not enter in its structure, and created a (Ionic Bond) between its atoms. Table (3-1) show some kinds of the inorganic detectors and chemical composition for it [84].

Table (3-1):- The Kinds of Inorganic Detectors[84]

No.	Detector	Chemical Composition
1	Zircon	$ZrSiO_4$
2	Quartz	SiO_2
3	Mica(Biotite) Mica (Muscovite)	$K(Mg, Fe)_3 AlSi_3O_{10}(OH)_2$ $Kal_3Si_3O_{10}(OH)_2$
4	Fluorite	$CaF_{10}(OH)_2$
5	Soda Lime Glass	$23SiO_2{:}5Na_2O{:}5CaO{:}Al_2O_3$
6	Olivine	$MgFeSiO_4$
7	Calcite	$CaCo_3$

3.2.2 Organic Detectors

Organic detectors are compounds where Carbon and Hydrogen enter in its structure, and create a (Covalent Bond) between its atoms, this type of SSNTDs have a sensitivity larger than inorganic detectors because the bonds of C-C, C-H which are easy broken after exposing to the radiation, also the organic detectors have a high analytic power larger than inorganic detectors. While the threshold energy for organic detectors is less than inorganic detectors [85].Table (3-2) show some kinds of the organic detectors and chemical composition for it [84].

Table (3-2):- The Kinds of Organic Detectors [84]

No.	Detectors	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	$C_6H_8O_9N_2$ (CN) $C_3H_4O_2$ (CT)
4	Polycarbonate (Lexan , Makrofol)	$C_{16}H_{14}O_3$ (PC)
5	Plexiglass	$C_5H_8O_2$
6	Polyallyldiglycol Carbonate	$C_{12}H_{18}O_7$ (CR-39)

The radiation damage in the solid state nuclear track detectors take two types:-

One. In Crystals:-

The damage consist of continuous disorder composed of vacant lattice sites and of interstitial ions or atoms, as show in figure (3-1a) [86].

Two. In Polymers:-

The damage causes to broken the long polymer chains in to short chains and result a new chain ends (Free Radicals) and other chemically reactive sites, as show in figure (3-1b) [86].

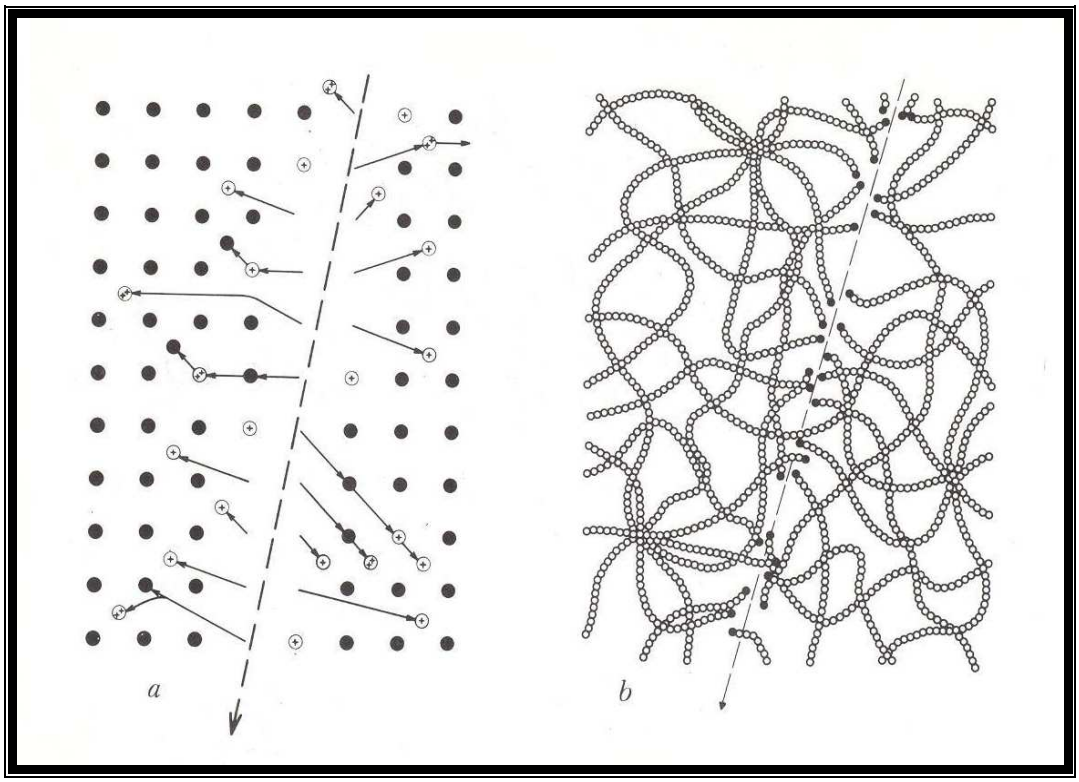


Figure (3-1):- The atomic character of a plastic track in (a) a crystal and (b) a polymer [86].

The latent track can be observed after using a chemical etchant analysis. Which make to analyze the damage regions, where the damage region have a high activity and effectiveness (in comparison with undamaged regions) [85]. The shape of the etched track depended on the charge, velocity of the incident particle, concentration and temperature of the etchant solution, in addition to the environmental circumstances.

3.3 Materials of Solid State Nuclear Track Detectors

Particles tracks may be formed in bulk samples of virtually any insulating material but not in metals or other good conductor [81]. Table (3-3) indicates the categories of track-storing and non track-storing materials and shows that there appears to be a correlation with electrical resistivity, such that materials with values above about (2000 ohm.cm) generally store tracks.

Table (3-3):- Relation of track formation to electric resistivity [81].

Materials	Resistivity Range (ohm.cm)
I- Track-Forming	
Insulators	10^{6} - 10^{20}
Poor Insulators: MoS_2	3000- 25000
Semiconductors: V_2O_5	2000 - 20000
II- Non Track-Forming	
• Semiconductors: Germanium, Silicon	10 – 2000
• Metals: Aluminum Copper, Gold, Platinum, Tungsten	10^{-6} – 10^{-4}

3.4 Threshold of Solid State Nuclear Track Detectors

The threshold for track registration can be defined as the minimum primary ionization energy required to occur track able for chemical etching [87]. The track formation should be related to the number of different parameters, such as total energy loss rate, primary ionization, restricted energy loss, type and energy of the ionized charge particle and also depend on the chemical structure of detector material, etc. [88,89]. Track formation is related to the production of dense regions of ionization by charged particle and to a first approximation, track formation can be regarded as occurring when the number of ions exceeds a certain threshold value. This threshold varies from one type of material to another. The track formation criterion, which takes the form of a statement that tracks are formed in a medium when, the chosen parameter exceeds some critical value [89].

These track formation criteria can be tested by irradiating a given solid with a number of ions at various energies and recording those cases for which etchable tracks are formed on diagram, such as figure (3-2) gives theoretical curves of the relative damage caused by different ions as a function of their velocities [86].

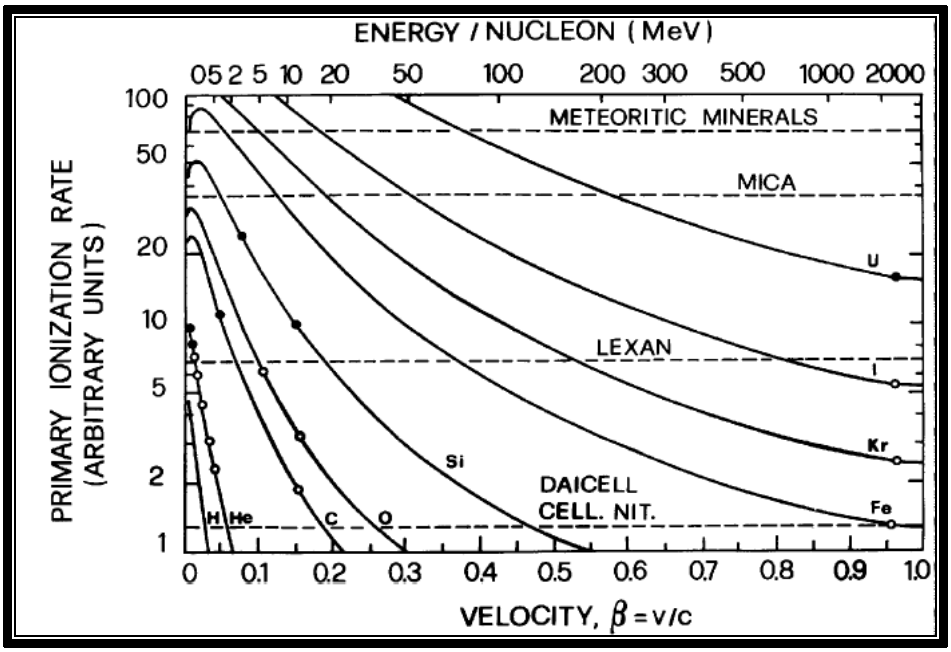


Figure (3-2):- Primary ionization rate for various heavy ions versus particle velocity and track etch threshold for various materials [86].

3.5 Tracks Formation in Inorganic Materials

3.5.1 The Ion- Explosion Spik Model

The production of damage regions in inorganic solids differs from those produced in polymers (organic solids). There are two important major factors in damage production; the primary and the secondary ionization by δ-electrons. In the case of inorganic solids, it obviously appears that the damage caused by interaction with the electrons in the detector [90].

This proposal postulates that the passage of a heavily- ionizing particle leaves a narrow region containing a high concentration of positive ions (burst ionization) in its wake. These arrays of adjacent ions are electrostatistically unstable and according to coulomb interaction, a mutual repulsion can drive these ions into interstitial positions provided that the time for electron ion recombination is less than the lattice vibration time (~ 10^{-13} second). Following ionization, an array of interstitial ions and vacant lattice sites are produced by coulomb energy. Subsequent processes include neutralization of

the positive ions and elastic relation of the local stresses by spreading the strain more widely around the track path figure (3-1a). In the final stage the long strain makes possible the direct observation of unetched tracks in crystals by Transmission Electron Microscope (TEM) or etch tracks by optical microscope. Figure (3-1a) shows the damage in the crystal consisting of continuous disorder composed of vacant lattice sites and of interstitial ions or atoms.

3.6 Tracks Formation in Organic Materials

In case of organic polymers the favorable theory for track formation is that based on the radio chemical damage mechanism.

The etched tracks are formed by the breaking of the long polymer chains to short chains when irradiated [91]. The result is new chain ends, i.e, chemically reactive sites are formed [90]. As it is known, the polymer is a chemical compound of large molecules which consist of a small repeated units called monomers. The monomer is a collection of atoms connected by covalent bonds. The passage of ionizing particles (e.g proton, deuteron, alpha- particle, etc.) through the polymer will excite and ionize the polymer molecules. Some excited molecules may in their turn, de excite through the emission of radiation or through non radioactive transitions. Excitation energy can also be transferred from one molecule to another figure (3-1b).

Both ions and excited molecular chains along its path so as to form a complex array of stable molecules, free radicals, ionized molecules and radical ions. Further reactions among these ions, free radicals and molecules will take place. However, because life time of these free ions is relatively small, only free radicals react among them or with other molecules [92,93]. Finally, the net effect on the plastic will be the production of many broken molecular chains, leading to reduction in the average molecular weight of the substance. Therefore, the rate of chemical etchant attack on a plastic increases

as the molecular weight decreases [90]. It is likely that the damage region is more etchable than the bulk material which leads to the etching a long the track and is greater in rate than that of the bulk material.

3.7 Track Affecting Parameter

There are two factors affected on the manifestation of track:

3.7.1 The Bulk Etch Rate Velocity

The rate of chemical etchant that attacks the undamaged region surrounding the track is termed the bulk etching velocity V_B . It is defined as the thickness that is removed from one of the surfaces of the detector as per time as a result of chemical etching effect. The bulk etching rate is a material parameter whose value depends on the structure homogeneity and isotropy of the material of SSNTDs. It is generally constant for a given material and for a given etchant applied under a specific set of etching condition, but in crystals it often depends on the crystallographic orientation [95], and it may vary in some polymers commensurably with the depth below the original surface of the detector. It follows that the bulk etching rate of a given detector material varies with the constituents of the chemical etchant, its concentration and temperature. It has been also found that for a given (isotropic & homogenous) material, the V_B varies exponentially with the etchant temperature for a constant concentration and is given by the following empirical formula [94].

$$\mathbf{V_B = A \exp (- E_B / KT)} \qquad \mathbf{(3\text{-}1)}$$

Where:

A = constant.

E_B = activation energy of bulk etching (Joul).

K = Boltzman's constant.

T = absolute temperature of the etching solution.

The unit of V_B is (µm/ s).

3.7.2 The Track Etch Rate Velocity

The track etch velocity V_T is the linear rate at which the detector material is etched out along the particle trajectory, i.e. it measures the amount of the removed layer of the detector along the incident particle trajectory per unit of etching time. The chemical etchant dissolves the damaged regions along the track path at a linear rate V_T and attacks the bulk material at a lesser rate V_B.

The track etching V_T is both a material and particle parameter. It depends on the material of the SSNTDs, their structural homogeneity and isotropy (however, it also depends on the crystallographic orientation in the crystals), the incident particle parameters (charge Z, mass M & energy E) and the etching conditions such as the concentration and temperature of the chemical etchant. It has been found that in a given irradiating and etching condition of a detector, the V_T is increase exponentially with the temperature of the etchant according to the following empirical formula [95].

$$\mathbf{V_T = B \exp (- E_T / KT) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3\text{-}2)}$$

Where:

B= constant.

T= absolute temperature of the etchant solution.

K= Boltzman's constant.

E_T = activation energy of the track etch.

3.8 Track's Diameter Growing Velocity

The diameter growing velocity V_d is defined as the changes in the average diameter of the opening etch pits per unit time of etching and it can be obtained by calculating the slope of diameter- time curve as [89]:

$$\mathbf{V_d = d / t = slope\ \ d(t)} \quad \text{……(3-3)}$$

Where d is the average diameter of the track opening and t is the etching time.

3.9 Critical Angle

The critical angle θ_C is the angle which controlled to emerging the tracks and is represents the minimum angle below which the tracks can not be observed by etching. i.e, when the dip angle θ (is the angle placed between the etched track and with the detector surface) less than critical angle θ_C , then the tracks can not be observed, and θ_C can be writing as [79]:

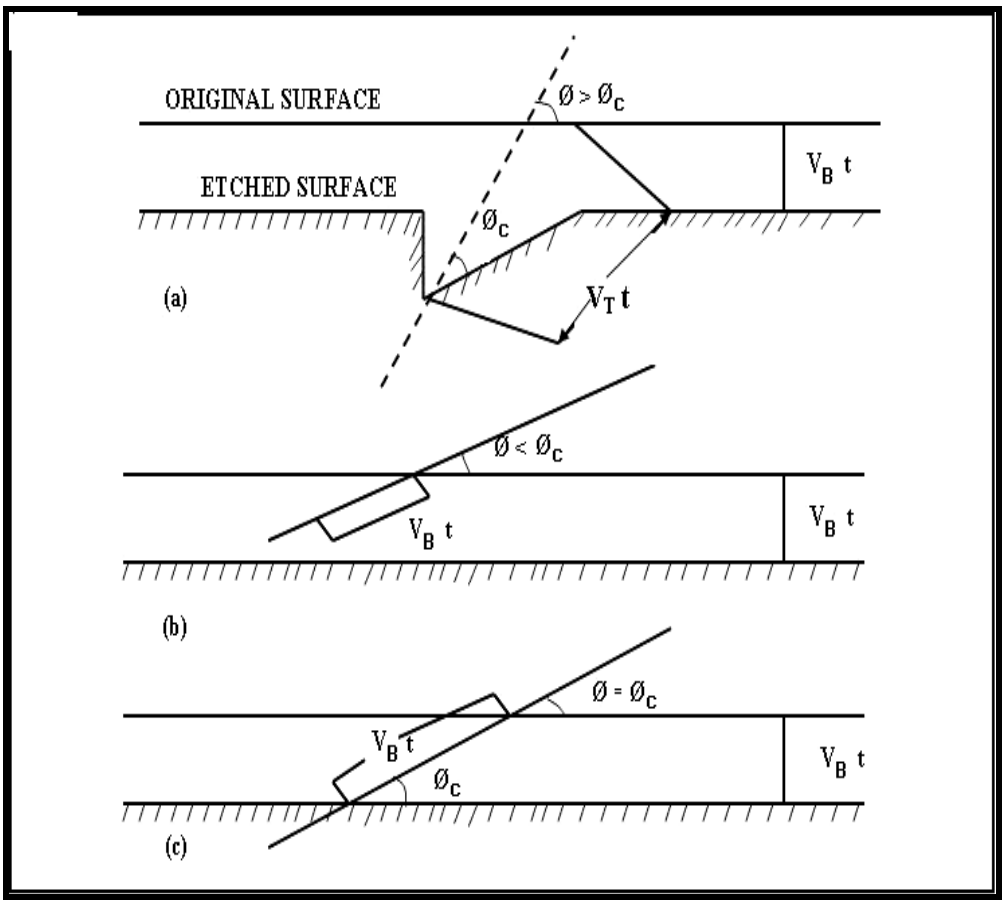
$$\theta_C = \sin^{-1} (V_B / V_T) \quad \text{…… (3-4)}$$

Only when normal component at the detector surface for etching rate velocity (V_T) is greater than general bulk etch rate (V_B) ($V_T \sin\theta > V_B$) then the track can be etching [86], but if ($V_T \sin\theta < V_B$) then the track cannot be observed and the critical state to emerging the tracks are [76]:

$$V_T \sin\theta = V_B \quad \text{…… (3-5)}$$

Figure (3-3) shows the developing etchant track consequent to incident angle [86] where (a) shows, the incident angle $\theta > \theta_C$ where the track pit is determined by the V_B and V_T , and how θ_C depends on them, (b) shows the

angle of incident $\theta < \theta_C$ where the surface is removed at a greater rate than the normal component of V_T and therefore , no track is observed and (c) shows, the incident angle $\theta = \theta_C$ where $\sin^{-1} (V_B / V_T)$ is the critical angle θ_C and how the track (in spite of being formed) fails to be developed.



Figure(3-3):- Track registration geometry with incidence angle of (a) $\theta > \theta_C$ (e.g. normal incidence), (b) $\theta < \theta_C$ and (c) $\theta = \theta_C$ (i.e critical angle)[86].

3.10 Etching Efficiency and Sensitivity

The etching efficiency is defined as the ratio of the counted tracks and the particle flounce impinge on the detector surface [95].

The efficiency η is given by:

η = No. of etched track / No. of incident particles …… (3-6)

$\eta = 1 - (V_B / V_T)$ ……(3-7)

or

$\eta = 1 - (1/ V)$ …… (3-8)

Where V is etching rate ratio (V_T / V_B)

This means that the value of the etching efficiency depends on the track etched rate velocity V_T and the bulk etched rate velocity V_B . The efficiency can also be defined in terms of the critical angle as follows:

$\eta = 1 - \sin \theta c$ …… (3-9)

Since : $\sin \theta c = V_B / V_T$

The experiments showing that the polymers track detectors have a high registration efficiency about (85 - 90 %) while most the glass detectors in the range (40 - 60 %).

Another etching parameter is termed etching sensitivity S is defined the ratio between etching velocity a long the track to the etching velocity at surface velocity and can be calculated using the following equations [78]:-

$S = (V_T / V_B) - 1$ …… (3-10)

$S = V - 1$ …….. (3-11)

$S = (1 / \sin \theta c) -1$ …… (3-12)

3.11 Track Etching Geometry

The track etching geometry depended on the critical angle for incident particle which makes with the surface detector. However, we can not recording the tracks when the angle of incident particle θ (placed between the particle passage and detector surface) less than critical angle.

We can visible the track when V_T greater than V_B , i.e $(V_T / V_B) > 1$.

The incident particles on the track detector can be identified by the charge Z or effective charge Z_{eff} , the mass M and the energy E or relativistic velocity ß (= ν/ c). The difference in these parameters of the incident particles produce changes in the track etching parameters, a total range of the particle through the detector material R (track length), the track etching velocity V_T and the variation of V_T with position along the track. The etched track has a conical shape and the easy measurable parameters are the conical etched-out length L_e and the diameter d of the etch pit opening.

The etched track formation process can be envisioned as the incident particle parameter (charge Z, mass M and energy E) representing the input parameters, while the etched track parameters (track length L_e , axes, profile and contour) represent the output parameters. The all processes in-between the above-mentioned parameters represent the damage formation and the etching principle [95]. In the simple instance is a particle penetrating a detector material to its original surface as in figure (3-4) [95].

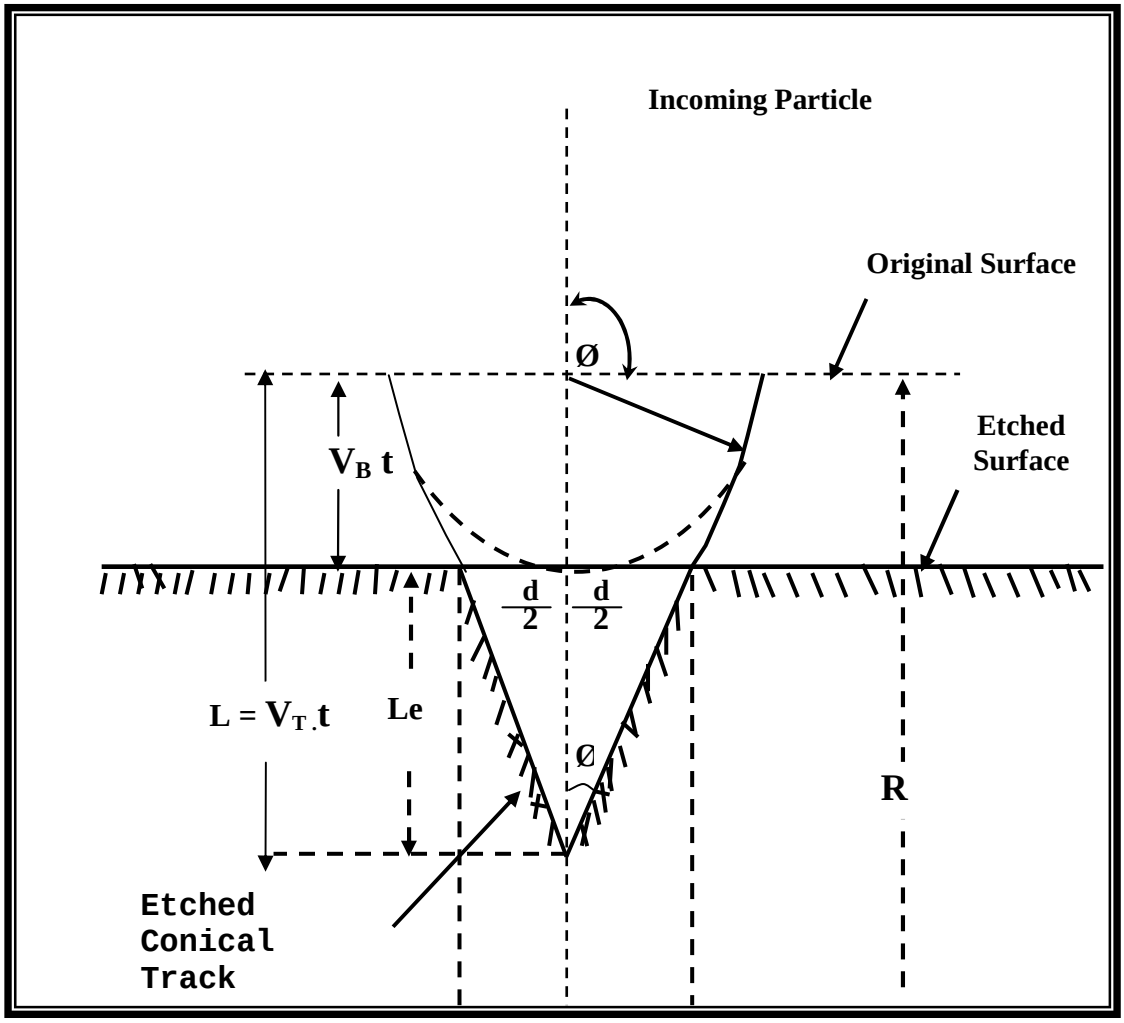


Figure (3-4):- A track geometry for particle penetrates a detector material normally [95].

The linear of attack down the track, i.e V_T , so that in an etching time t, the etch pit will extend to a distance L from the point of origin, then [86]:

$$L = V_T \cdot t \quad \text{..... (3-13)}$$

The surface is also being removed at a rate V_B , so the full length of the etch pit is [95].

$$\mathbf{L_e = V_T \, . \, t - V_B \, . \, t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3\text{-}14)}$$

The diameter of the etch pit is related to V_B and V_T according to this equation [95]:

$$\mathbf{d = 2V_B \, . \, t \, [\, (V_T - V_B \,) \, / \, (V_T + V_B \,)]^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3\text{-}15)}$$

and the removed surface thickness h is [9]:

$$\mathbf{h = V_B \, . \, t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3\text{-}16)}$$

The etching rate ratio is represented in this equation:

$$\mathbf{V = V_T \, / \, V_B} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3\text{-}17)}$$

It is clear from these equations that, the track diameter d and the length of the etched track L_e depend essentially on the competitive effects of V_T and V_B. When $V_B = V_T$ both L_e and d vanishes, then no track produces.

3.12 The Chemical Etching

Ionizing particles passing through polymeric track detectors produce latent track, which are trails of radiation damage [91]. The best means of observing the tracks is by etching the SSNTDs material with a chemical solution, which preferentially attacks, the damaged material and enlarges the original track [97], to a size, which is visible in the optical microscope. In general, etchants for polymeric detectors are frequently solutions of alkali hydroxides such as NaOH or KOH with (1-12)N at (40-60) °C [81]. For glasses and minerals crystals such as quartz, mica and certain pyroxenes etched in aqueous solutions of acids such as (HF) with ~ 48% concentration at 20 °C [74].

Etching times can vary from few seconds to many hours. It varies according to the exact etching conditions; the temperature and the concentration of the etchant.

The chemical etching process depend on several parameters are [21].

1- Type and composition etching solution.

2- The concentration of the etching solution.

3- Temperature of the etching solution.

4- Etching time.

3.13 CR-39 Track Detector

CR-39 is organic detector and was first discovered by Cartwright, Shirk and Price (1978) [36]. The chemical composition for CR-39 is ($C_{12}H_{18}O_7$) and have density (1.32 $g.cm^{-3}$). The CR-39 products can be made from a liquid monomer which is made by polymerization in the form of highly crosslinked in to homopolymers, copolymers (usually methyl methacrylate and vinyl acetate) or intermediate products [36]. The plastic CR-39 have a

specific name called poly ally digycal carbonate and supplied by a company of Pershore Moulding, Ltd, England [92].

The symbol CR-39 was given according to the " Columbia Resins " [95]. The general structure for monomer is contain from two groups of ally is (CH_2-CH=CH_2-) as show in figure (3-5).

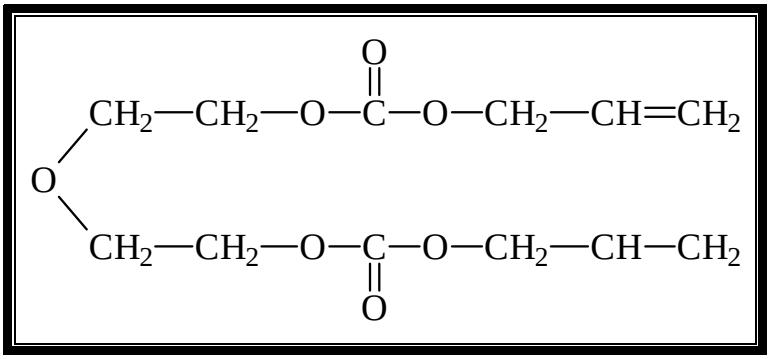


Figure (3-5):- The chemical form of CR-39 plastic [95].

The detector (CR-39) has a high efficiency to record the tracks in company with other detectors and it has some specifications as:

1. Optically transparent
2. Very sensitive to radiation
3. Highly isotropic and homogeneous
4. Not cross-linking after radiation damage has broken the chemical bonds
5. Having a non-solvent chemical etchant
6. This polymer is resistant almost to all solvents and the heating.

The use of the CR-39 plastic as a nuclear particle detector has become generalized in the fields of dosimetry, spectroscopy and environmental science due to its high sensitivity. Most of the applications of this detector are in proton, alpha and neutron dosimetry and radiography as well as for radon dosimetry and cosmic rays studies [97].

5.1 Results

In this study (65) blood samples of injured people males and females were taken from (11) Iraq governorates. (42) of these samples which belong to non-occupational people were collected from Al- Yarmook hospital, others which belong to (23) occupational people were collected from some workers in the ministry of science and technology.

5.2 Calibration Curve

Standard of different uranium concentrations samples has been prepeard to calibration our studying samples. Using known standard uranium supplied from the IAEA (international atomic energy agency) different weights of standards uranium mixing with samples, make them pellet than put on it CR-39 and irradiated with the same neutron source for also seven days. Take the studying samples to get the calibration curve with the assessment of this equation:

Standard uranium weight (known) × its concentration (Known) = weight sample (known) × wanted concentration

Figure (5-1) represent the calibrations curve for uranium standard samples and track density.

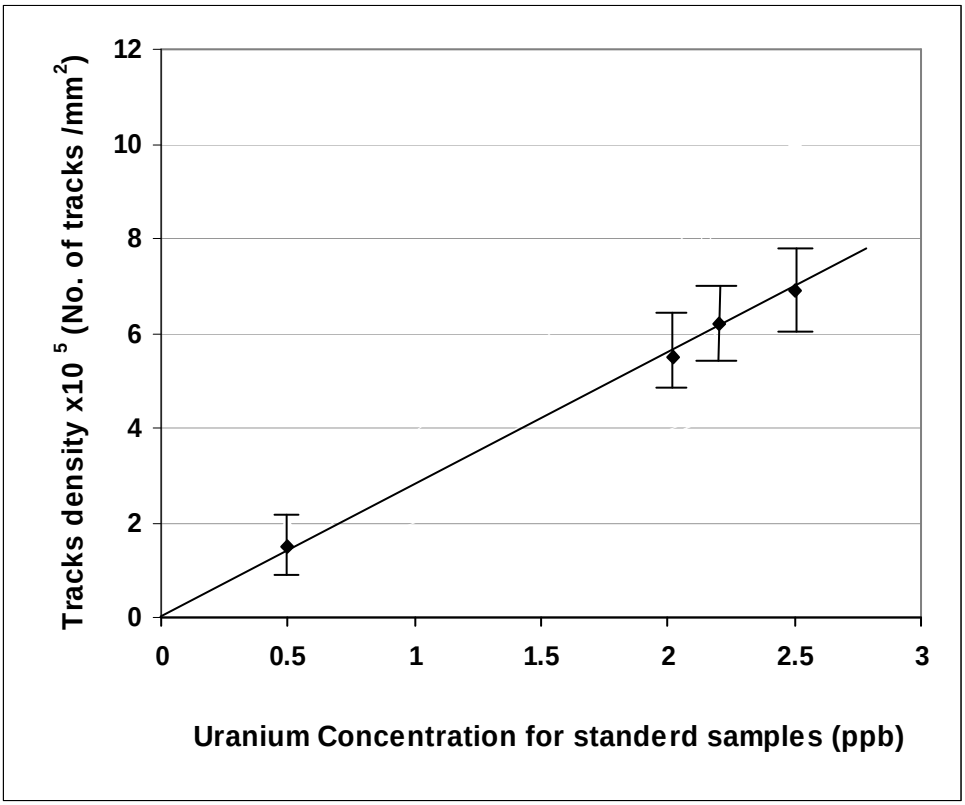


Figure (5-1):- The relation of uranium concentration and track density in the standard samples [24].

5.3 Uranium Concentration in Blood Samples of Non Occupational and Occupational Workers

Table (5-1) and (5-2) shows that the average of uranium concentration in blood samples for non occupational workers was (0.52 ppb) and for workers was (0.86 ppb), as shown in figure (5-2).

The maximum and minimum of uranium concentration in non occupational workers and occupational workers were (1.84 ppb) (female, 63 years old) lived in Al-Muthana governorate, (1.99 ppb) (male, 36 years old) lived in Al- Basrah governorate and (o.25 ppb) (male, 38 years old) lived in Al-Ramadi governorate, (0.095 ppb) (male, 22 years old) lived in Baghdad governorate, respectively as shown in figure (5-3).

Table (5-1):- Uranium Concentrations in Blood Samples of Non Occupational from Different Governorates of Iraq

No.	Location	Gender	Age (year)	Track density $\rho \times 10^5$ (No. of tracks /mm^2)	Uranium concentration (ppb)
1	Diyala	female	25	2.06 ± 0.21	0.51
2	Baghdad	female	48	1.38 ± 0.17	0.34
3	Baghdad	female	20	2.02 ± 0.15	0.501
4	Baghdad	female	19	1.75 ± 0.23	0.43
5	Baghdad	female	17	1.61 ± 0.21	0.39
6	Baghdad	female	19	1.83 ± 0.27	0.45
7	Baghdad	male	17	1.9 ± 0.25	0.47
8	Baghdad	male	20	1.51 ± 0.14	0.38
9	Ramadi	male	14	1.63 ± 0.14	0.404
10	Baghdad	female	20	1.18 ± 0.19	0.29
11	Bable	male	17	1.2 ± 0.17	0.29
12	Baghdad	male	20	2.52 ± 0.38	0.62
13	Musal	female	15	1.91 ± o.23	0.47
14	Ramadi	male	38	2.02 ± 0.23	0.25
15	Ramadi	male	42	1.42 ± 0.15	0.35
16	Kadesea	male	20	1.53 ± 0.22	0.38
17	Baghdad	male	20	1.79 ± 0.19	0.44
18	Baghdad	female	22	1.65 ± 0.19	0.41
19	Baghdad	female	26	1.63 ± 0.17	0.4
20	Diyala	male	20	2.06 ± 0.36	0.51
21	Kadesea	female	21	1.42 ± 0.15	0.35
22	Baghdad	male	50	1.81 ± 0.35	0.45
23	Baghdad	male	29	2.24 ± 0.24	0.56

24	Bable	male	36	2.24 ± 0.13	0.56
25	Basrah	female	32	1.73 ± 0.24	0.43
26	Ramadi	male	43	1.57 ± 0.19	0.39
27	Musal	male	18	1.85 ± 1.9	0.46
28	Ramadi	female	34	1.79 ± 0.27	0.44
29	Anbar	male	19	1.65 ± 0.25	0.41
30	Baghdad	male	55	3.14± 0.427	0.78
31	Wusat	male	18	2.05 ± 0.441	0.51
32	Baghdad	male	22	3.5 ± 0.47	0.87
33	Ramadia	male	61	2.7 ± 0.26	0.69
34	Diyala	male	19	1.48 ± 0.23	0.37
35	Ramadi	male	72	3.1 ± 3.03	0.76
36	Baghdad	male	67	1.48 ± 0.15	0.37
37	Ramadi	female	55	3.14 ± 0.51	0.78
38	Anbar	female	65	2.93 ± 0.48	0.73
39	Alnasiriya	femae	21	2.53 ± 0.59	0.63
40	Omarah	female	36	1.57 ± 0.22	0.39
41	Muthana	female	63	7.41 ± 2.72	1.84
42	Baghdad	female	23	3.11 ±0.38	0.77
					Average = 0.52

Table (5-2):- Uranium Concentrations in Blood Samples for Workers in Ministry of Science and Technology

No.	*Location*	*Gender*	*Age (year)*	*Number of working Years*	*Tracks density $\rho \times 10^5$ (No. of tracks /mm^2)*	*Uranium concentration (ppb)*
1	Baghdad	male	36	13	1.44 ± 0.23	0.36
2	Baghdad	male	58	30	4.77 ± 0.59	1.19
3	Baghdad	female	37	1	3.63 ± 0.69	0.902
4	Baghdad	female	29	1	1.82 ± 0.5	0.45
5	Baghdad	male	40	10	5.16 ± 0.56	1.28
6	Baghdad	female	45	15	3.43 ± 0.29	0.85
7	Baghdad	male	52	21	3.47 ± 0.36	0.86
8	Baghdad	male	56	21	3.51 ± 0.37	0.87
9	Diyala	male	23	1	1.51 ± 0.14	0.38
10	Diyala	female	49	19	5.59 ± 0.6	1.38
11	Diyala	male	22	1	1.92 ± 0.27	0.48
12	Baghdad	female	34	12	3.02 ± 0.54	0.75
13	Baghdad	male	25	6	2.45 ± 0.22	0.61
14	Baghdad	female	40	10	1.1 ± 0.18	0.27
15	Diyala	female	32	11	5.67 ± 0.6	1.41
16	Baghdad	female	30	9	4.29 ± 0.45	1.1
17	Baghdad	male	60	20	3.34 ± 0.46	0.83
18	Ramadi	male	25	5	1.96± 0.3	0.49
19	Baghdad	female	25	5	3.2 ± 0.27	0.79
20	Basrah	male	36	12	8 ±1.96	1.99
21	Ramadi	male	63	30	2.37 ± 0.32	0.59
22	Baghdad	male	22	1	0.38 ± 0.067	0.095
23	Basrah	female	38	22	7.1 ±0.092	1.76
						Average = 0.86

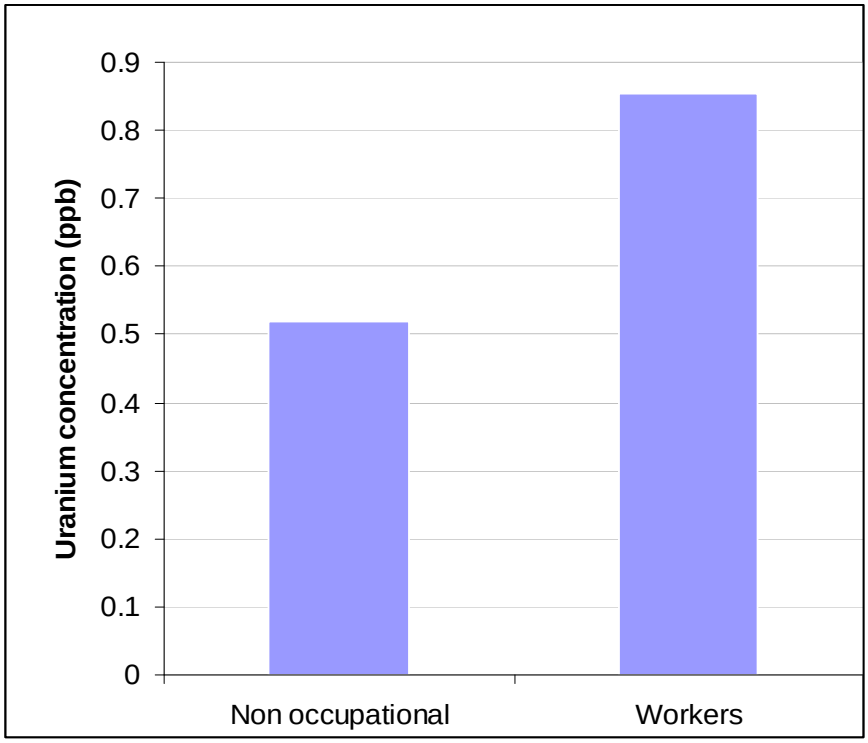


Figure (5-2):- The average of uranium concentration for non occupational and workers in ministry of science and technology

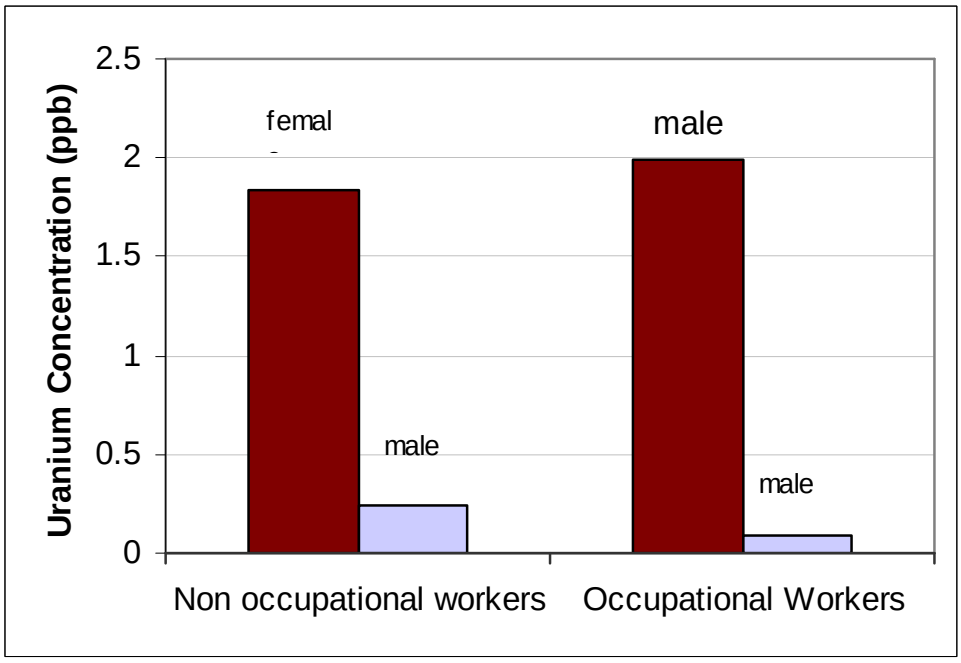


Figure (5-3):- Maximum and minimum of uranium concentration in blood samples for occupational and non occupational workers

5.4 Uranium Concentration for Males and Females Blood Samples of Non Occupational workers

Tables (5-3), (5-4) present uranium concentrations for males and females blood samples for different governorates of Iraq.

From these tables, the average of uranium concentration for males and females are (0.49 ppb), (0.57 ppb) respectively, as shown in figure (5-4).

The maximum and minimum of uranium concentration for males and females were (0.87 ppb) (male, 22 years old) lived in Alyusifiya governorate, (1.84 ppb) (female, 63 years olds) lived in Al Muthana governorate and (0.25 ppb) (male, 38 years old) lived in Ramadi governorate, (0.29 ppb) (female, 20 years old) lived in Baghdad governorate respectively, as shown in figure (5-5).

Table (5-3):- Uranium Concentrations for Males Blood Samples of Non Occupational Workers

No.	Location	Age (year)	Track density $\rho \times 10^5$ (No. of tracks /mm^2)	Uranium concentration (ppb)
1	Baghdad	17	1.9 ± 0.25	0.47
2	Baghdad	20	1.51 ± 0.14	0.38
3	Ramadi	14	1.63 ± 0.14	0.4
4	Bable	17	1.2 ± 0.17	0.29
5	Bable	20	2.51 ± 0.38	0.62
6	Ramadi	38	2.02 ± 0.23	0.25
7	Ramadi	42	1.42 ± 0.15	0.35
8	Kadesea	20	1.53 ± 0.22	0.38
9	Baghdad	20	1.79 ± 0.19	0.44
10	Diyala	20	2.06 ± 0.36	0.51
11	Baghdad	50	1.81 ± 0.35	0.45
12	Baghdad	29	2.24± 0.24	0.56
13	Bable	36	2.24 ± 0.13	0.56
14	Ramadi	43	1.57 ± 0.19	0.39
15	Musal	18	1.85 ± 1.9	0.46
16	Anbar	19	1.65 ± 0.25	0.41
17	Baghdad	55	3.14 ± 0.42	0.78
18	Wasut	18	2.05 ±0.44	0.51
19	Baghdad	22	3.5 ± 0.47	0.87
20	Ramadi	61	2.7± 0.27	0.69
21	Diyala	19	1.48 ± 0.23	0.36
22	Ramadi	72	3.1 ±3.03	0.76
23	Baghdad	67	1.48 ± 0.15	0.37
				Average = 0.49

Table (5-4):- Uranium Concentrations for Females Blood Samples of Non Occupational Workers

No.	Location	Age (year)	Track density ρ ×10^5 (No. of tracks /mm^2)	Uranium Concentration (ppb)
1	Diyala	25	2.06 ± 0.21	0.51
2	Baghdad	48	1.38 ± 0.17	0.34
3	Baghdad	20	2.02 ± 0.15	0.5
4	Wasut	19	1.75± 0.23	0.43
5	Baghdad	17	1.61 ± 0.21	0.39
6	Baghdad	19	1.83 ± 0.27	0.45
7	Baghdad	20	1.18 ± 0.19	0.29
8	Musal	15	1.91 ± 0.23	0.47
9	Baghdad	22	1.65 ± 0.18	0.41
10	Kadesea	21	1.42 ± 0.15	0.35
11	Basrah	32	1.73 ± 0.24	0.43
12	Ramadi	34	1.79 ± 0.27	0.44
13	Ramadi	55	3.14 ±0.51	0.78
14	Anbar	65	2.93 ± 0.48	0.73
15	Alnasiriya	21	2.53 ± 0.59	0.63
16	Omarah	36	1.57 ± 0.22	0.39
17	Muthana	63	7.41 ± 2.72	1.84
18	Baghdad	23	3.11 ± 0.38	0.77
				Average = 0.57

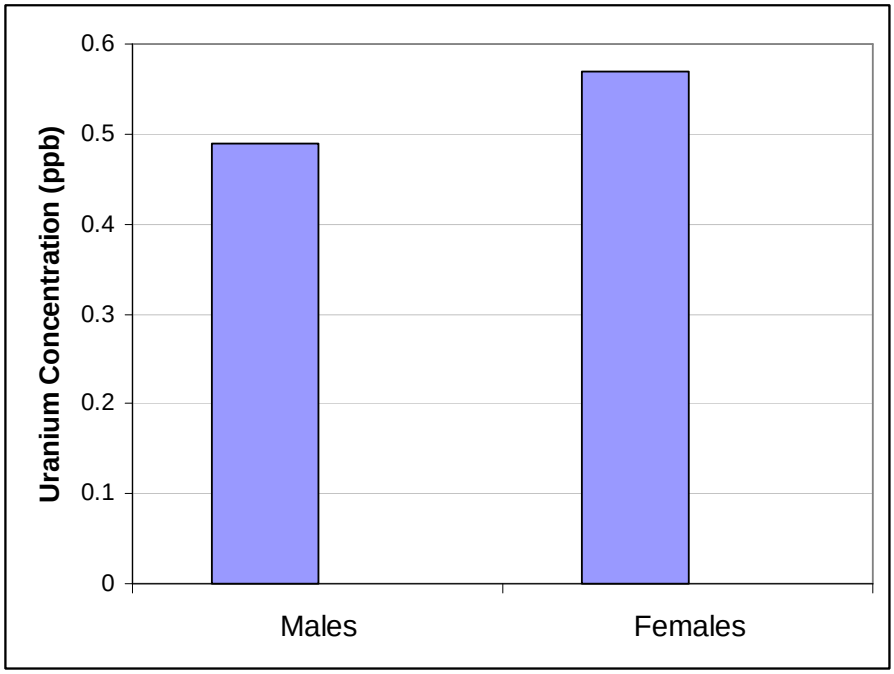


Figure (5-4):- The average of uranium concentration in blood for males and females of non occupational workers

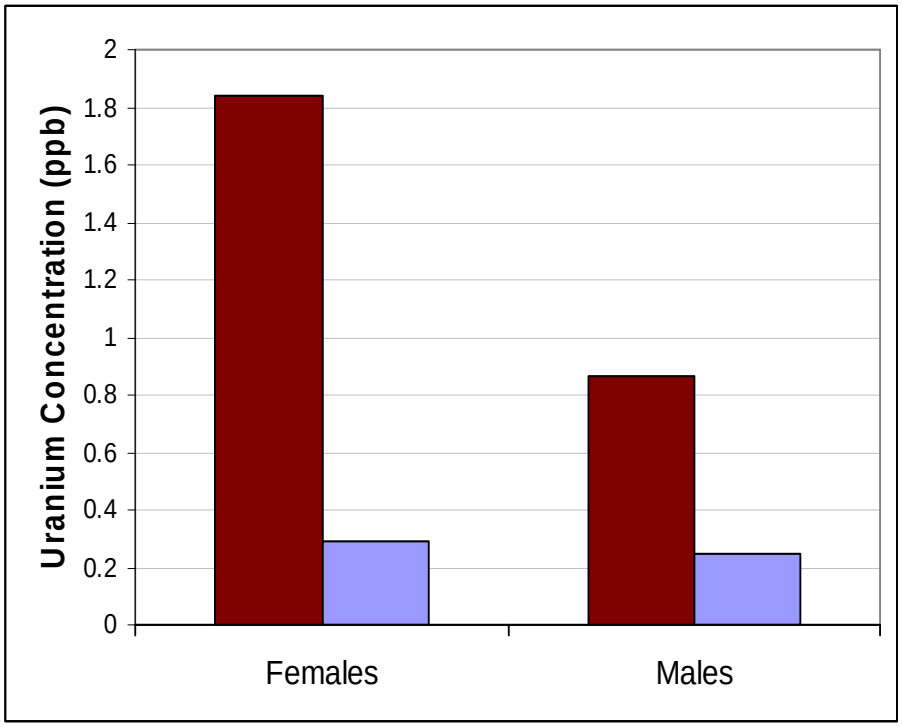


Figure (5-5):- Maximum and minimum of uranium concentration for females and males of non occupational workers

5.5 Uranium Concentration for Males and Females Blood Samples of Workers in Ministry of Science and Technology

Tables (5-5), (5-6) represent the uranium concentrations for males and females blood samples of workers in ministry of science and technology.

From these tables the average of uranium concentration were (0.77 ppb), (0.97 ppb) for males and females respectively, as shown in figure (5-6).

The maximum and minimum of uranium concentration for males and females were (1.99 ppb) (male, 36 years old and 12 years working in ministry of science and technology), (1.76 ppb) (female, 38 years old and 22 year working in ministry of science and technology) and (0.095 ppb) (male, 22 years old and 1 years working in ministry of science and technology), (0.27 ppb) (female, 40 years old and 10 years working in ministry of science and technology) respectively, as shown in figure (5-7).

Table (5-5):- Uranium Concentrations for Males Blood Samples of Workers in Ministry of Science and Technology

No.	Location	Age (year)	Number of working years	Track density $\rho \times 10^5$ (No. of tracks /mm^2)	Uranium Concentration (ppb)
1	Baghdad	36	13	1.44 ± 0.23	0.36
2	Baghdad	58	30	4.77 ± 0.59	1.19
3	Baghdad	40	10	5.16 ± 0.56	1.28
4	Baghdad	52	21	3.47 ± 0.36	0.86
5	Baghdad	56	21	3.51 ± 0.37	0.87
6	Diyala	23	1	1.51 ± 0.136	0.38
7	Diyala	22	1	1.92 ± 0.27	0.48
8	Baghdad	25	6	2.45 ± 0.22	0.61
9	Baghdad	60	20	3.34 ± 0.46	0.83
10	Ramadi	25	5	1.959 ± 0.3	0.49
11	Basrah	36	12	8 ± 1.96	1.99
12	Ramadi	63	30	2.37 ± 0.32	0.59
13	Baghdad	22	1	7.1 ± 0.067	0.095
					Average = 0.77

Table (5-6):- Uranium Concentrations for Females Blood Samples of Workers in Ministry of Science and Technology

No.	Location	Age (year)	Number of working years	Track density $\rho \times 10^5$ (No. of tracks /mm^2)	Uranium Concentration (ppb)
1	Baghdad	37	1	3.63 ± 0.69	0.9
2	Baghdad	29	1	1.816 ± 0.5	0.45
3	Baghdad	45	15	3.428 ± 0.29	0.85
4	Diyala	49	19	5.59 ± 0.6	1.38
5	Baghdad	34	12	3.02 ± 0.54	0.75
6	Baghdad	40	10	1.1 ± 0.18	0.27
7	Diyala	32	11	5.67 ± 0.6	1.41
8	Baghdad	30	9	4.29 ± 0.45	1.1
9	Baghdad	25	6	3.2 ± 0.27	0.79
10	Basrah	38	22	7.1 ±0.092	1.76
					Average = 0.97

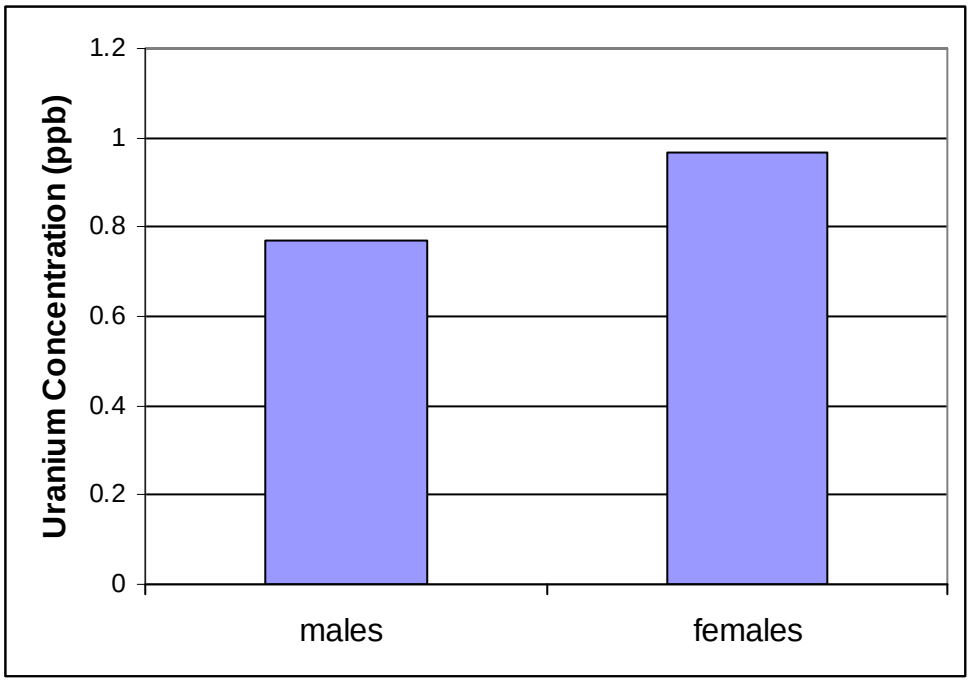


Figure (5-6):- The average of uranium concentration in blood for males and females for workers in ministry of science and technology

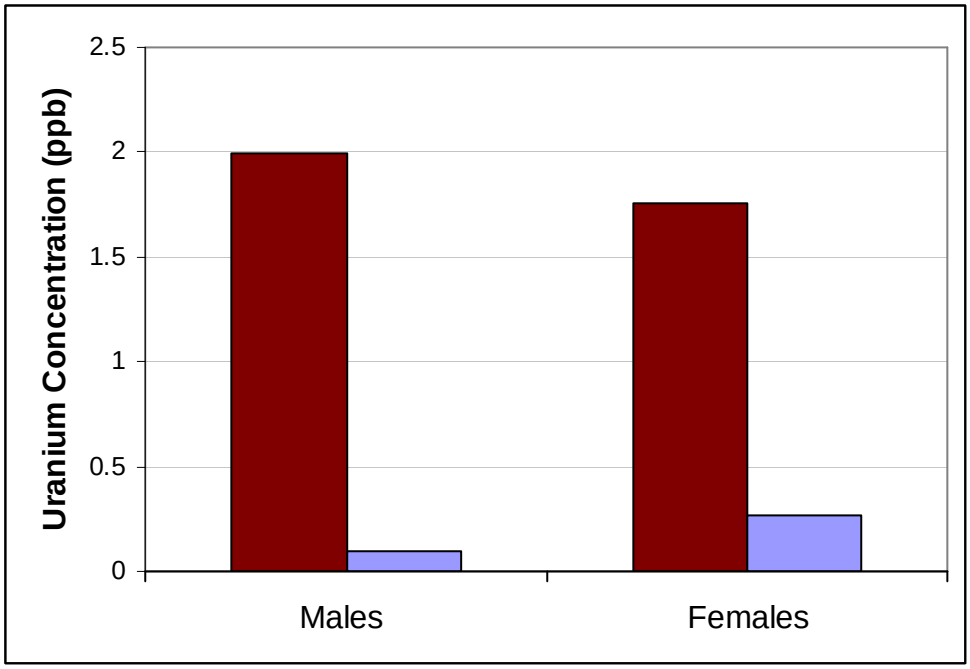


Figure (5-7):- The maximum and minimum of uranium concentration in blood for males and females for workers in ministry of science and technology

5.6 Uranium Concentration in Blood Samples for Different Governorates of Iraq

Figure (5-8) shows the average of uranium concentrations in blood samples for different governorates of Iraq, which shows that the maximum of uranium concentration for non occupational workers was (1.84 ppb) in Al-Muthana governorate and the minimum concentration was (0.25 ppb) in Al-Dywania governorate.

Figure (5-9) shows the average of uranium concentration in blood samples for different governorate of Iraq for workers in ministry of science and technology, which shows that the maximum of uranium concentration was(1.87 ppb) in Al Basarh and minimum concentration (0.54 ppb) in Al Anbar governorate.

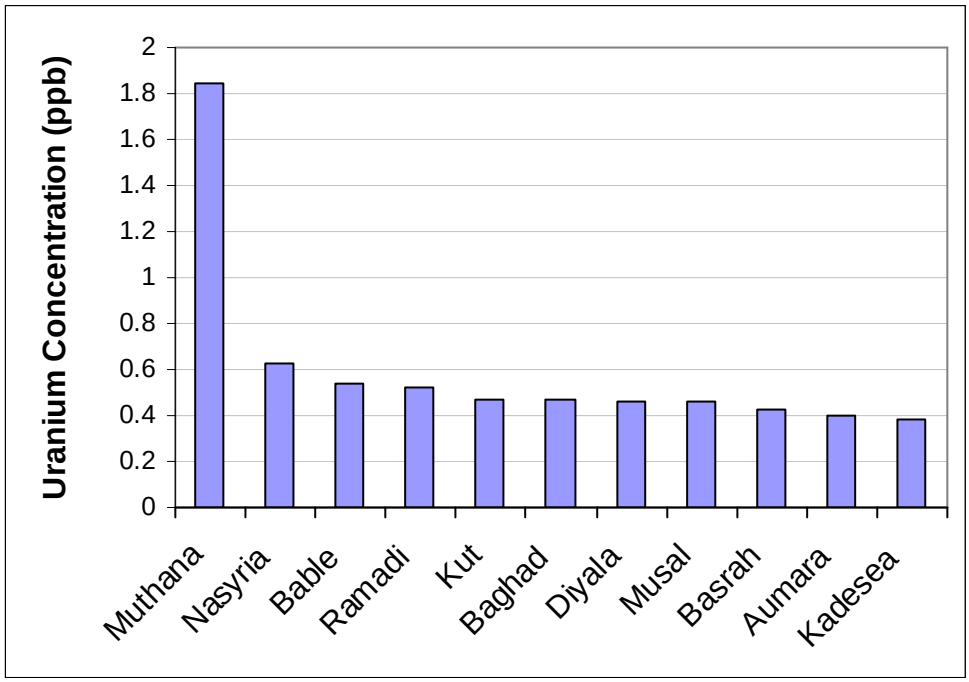


Figure (5-8):- The average of uranium concentration in blood for different governorates of Iraq and for non occupational workers

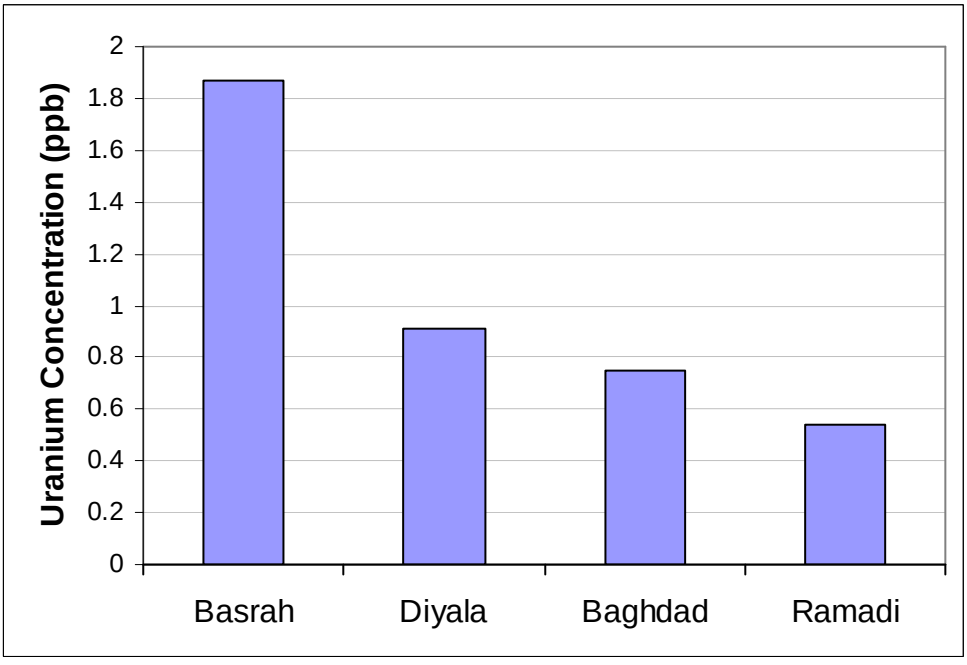


Figure (5-9):- The average of uranium concentration in blood for different governorates of Iraq and for workers in ministry of science and technology

5.7 Uranium Concentration in Blood for Workers in Ministry of Science and Technology According to the Number of Working Years

Table (5-7) and figure (5-10) shows the average of uranium concentrations in blood samples for workers in ministry of science and technology according to the number of working years.

It was found that the following divisions were the most appropriate, as it provides an acceptable statistical number in each group: (A) (1-5) years, (B) (6-10) years, (C) (11-15) years (D) (16-20) years and (E) (21-25) years.

Figure (5-10) shows that the uranium concentration in the blood samples of workers increased with the number of working years and was higher than that of control group in the different governorates of Iraq.

Table (5-7):- Average of Uranium Concentrations in Blood Samples for Workers in Ministry of Science and Technology According to the Number of Working Years

Group	Number of working years	Average of uranium concentration (ppb)
A	1-5	0.466
B	6-10	0.81
C	11-15	1.07
D	16-20	1.1
E	21-25	1.16

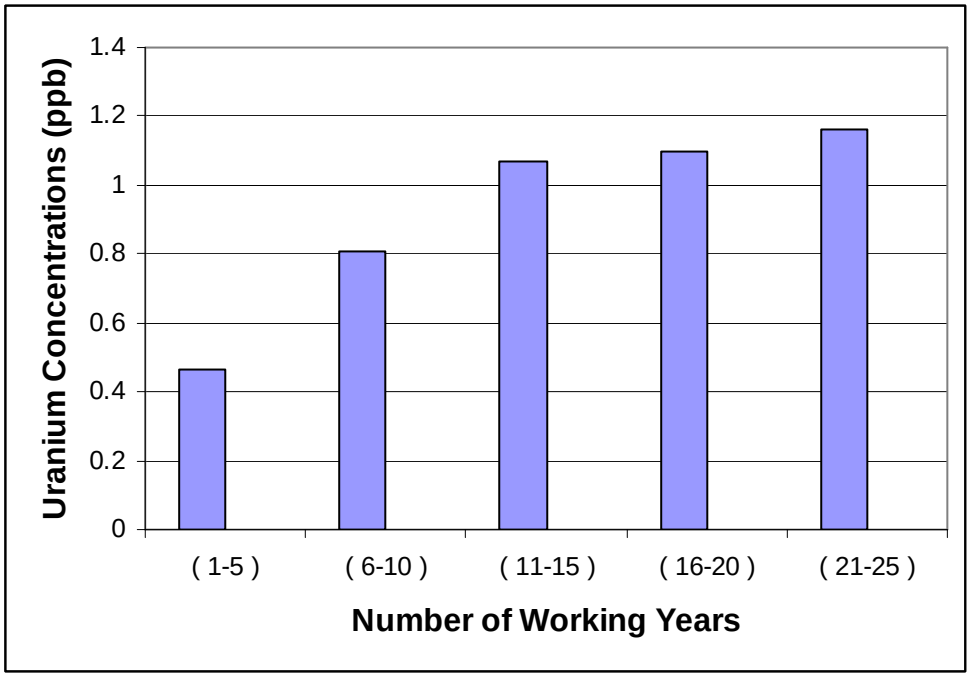


Figure (5-10):- The average of uranium concentration in blood of workers in ministry of science and technology according to the numbers of working years

5.8 Conclusions

1. The uranium levels in the blood of workers in ministry of science and technology were higher than the value from non occupational workers.
2. The uranium concentration in the blood of workers increased with increasing number of years worked in the ministry of science and technology.
3. The highest of uranium concentration in the blood for non occupational workers was found in Al- Muthana governorate (1.84 ppb) which indicate that this governorate was military practices through (1991) war and weapons waste still being in this region, while the lowest of uranium concentration was in Al- Ramadi governorate (0.248 ppb).
4. The average of uranium concentration for females (0.96 ppb) for workers and (0.68 ppb) for non workers were higher than for males (0.77 ppb) for workers and (0.59 ppb) for non workers.
5. Results show that the uranium concentration in the blood is below the allowed limit from ICRP agency (0.115 ppm).
6. The age of people are a not good indicator for uranium concentration in blood because the southern governorates contaminate with depleted uranium.
7. The results show that the uranium concentrations for females blood samples are larger than for males blood samples because the total blood volume in females is (4-5) litters, while in males is (5-6) litters.

5.9 Future Works

1. Determination of uranium concentration in urine and hair samples by using CR-39 track detectors.
2. Determination of uranium concentration in blood of workers in phosphate mines.
3. Determination of the alpha emitters concentration in the human tissues.

2.1 Radioactivity

Radioactivity is the number of disintegrations per second, its unit for measurement is Becquerel [25]. There are two main sources of radiation found in the environment: Natural Radioactivity Sources (which include terrestrial, cosmic rays and cosmogenic) and Man-Made Radioactivity Sources (which include medical, fallout and nuclear power) [25,26,27].

2.1.1 Natural Radioactivity Sources

Natural radioactivity in earth crust belongs to the primordial radio nuclides, which are widely distributed through the earth's crust and have long half-lives. They can be divided in to those that occur singly such as potassium-40 and rubidium-87 whose half -lives (1.3×10^9) and (4.8×10^{10}) years respectively [28], and those which occur in series chains such as uranium -238 series, actinium series, thorium series and neptunium series. The importance of these chains come according to their half life, abundance in nature and type of radiation emitted from them (Table 2-1) [29].

Table (2-1):- Natural Radioactivity Series [29].

Series	**First isotope**	**Half-life(years)**	**Last isotope**
Uranium	^{238}U	4.49×10^9	^{206}Pb
Actinium	^{235}U	7.10×10^8	^{207}Pb
Thorium	^{232}Th	1.39×10^6	^{208}Pb
Neptunium	^{237}Np	2.14×10^6	^{209}Bi

Only three of these decay series are found in nature: Uranium, Actinium and Thorium. This is because the isotope ^{237}Np has a half -life much shorter than the geological age of the earth which about 5 billion years [30].

The assessment of environmental radioactivity for any region is very important to detect any event that causes radioactive contamination [31]. The dose from external environmental radiation will vary widely from location to location depending on the abundance of natural radioactive ores in rocks and soil [32].

With regards to depleted uranium two series are important: the Uranium series and the Actinium series [30].

2.1.1. A: Uranium -238 Series

This series begins with uranium -238 nuclei (half - life 4.49 x 10^9 years) and gradually converted to lead -206, which is a stable element, through sequences of the emission of alpha and beta particles. The elements of this series are represented in (Table 2-2) [33,34].

Table (2-2):- Uranium - 238 Decay Series [33, 34].

Nuclide	**Half - Life**	**Radiation**
U-238	4.49 x10^9 years	Alpha
Th-234	24.1 days	Beta
Pa-234m	1.18 minutes	Beta
U-234	2.48 x 10^5 years	Alpha
Th-230	7.52 x 10^4 years	Alpha
Ra-226	1600 years	Alpha
Rn-222	3.825 days	Alpha
Po-218	3.05 minutes	Alpha
Pb-214	26.8 minutes	Beta
Bi-214	19.7 minutes	Beta
Po-214	1.6 x 10^{-4} second	Alpha
Pb-210	22 years	Beta

Bi-210	5.01 days	Beta
Po-210	138.4 days	Alpha
Pb-206	Stable	—

2.1.1.B: Actinium -235 Series

This series begins with uranium- 235 nuclei (half -life 7.10 x 10^8 years), which has the longest half -life compared to other elements in this series and ends with lead -207 ,which is a stable element. The elements of this series are represented in (Table 2-3) [33,34].

Table (2-3) :- Actinium -235 Decay Series [33, 34]

Nuclide	**Half-life**	**Radiation**
U-235	7.10 x 10^8 years	Alpha
Th-231	25.6 hours	Beta
Pa-231	3.98 x 10^4 years	Alpha
Ac-227	22 years	Beta
Th-227	18.17 days	Alpha
Ra-223	11.7 days	Alpha
Rn-219	3.92 seconds	Alpha
Po-215	1.83 x 10^{-3} seconds	Alpha
Pb-211	36.1 minutes	Beta
Bi-211	2.15 minutes	Alpha
Po-211	0.52 seconds	Alpha
Ti-207	4.79minutes	Beta
Pb-207	Stable	–

The importance of uranium-235 is the ability of fast fission by using thermal neutrons.

2.1.1.C: Thorium-232 Series

Thorium was discovered by "J.Berzelins", which is derived from the Scandinavian "thor". This series begin with thorium-232 nuclei (half-life $1.39x10^{9}$ years) and end with lead -208 isotope. The elements of this series are represented in (Table 2-4) [33,34].

Table (2-4):- Thorium-232 Decay Series [33,34].

Nuclide	**Half – life**	**Radiation**
Th-232	$1.39x10^{9}$ years	Alpha
Ra-228	6.7 years	Beta
Ac-228	6.13 hours	Beta
Th-228	1.9 years	Alpha
Ra-224	3.64 days	Alpha
Rn-220	54.5 seconds	Alpha
Po-216	0.158 seconds	Alpha
Pb-212	10.6 hours	Beta
Bi-212	60.6 minutes	Beta
Ti-208	3.1 minutes	Beta
Po-212	$3.0x10^{-7}$ seconds	Alpha
Pb-208	Stable	——

2.1.1.D: Neptunium -237 Series.

Neptunium has a half - life ($2.14x10^{6}$years), which is much shorter than the geological age of the earth. Virtually all neptunium decayed within the first 50 millions of years after the earth was found [30].So neptunium -237 did not find in nature but it was discovered in some stars spectrum [29].

2.1.2 Man-Made Radioactivity Sources

Over the last few decades man has "artificially" produced several hundred radionuclides, and the power of the atom used for a wide variety of purposes, medicine, weapon the production of energy detection of fires, illuminating watches and prospecting for minerals. All increase the radiation dose both to individual people and to man-kind as a whole.

The variability is generally greater for man -made sources than for natural ones. Most made sources, too, can be controlled more readily than most natural ones, through exposure to external irradiation to fall-out from past nuclear explosion [25, 27].

2.2 Natural Uranium

Uranium is considered one of the most important primordial radionuclides in the earth crust. It was discovered in 1789 by Klaproth, and drive its name uranus planet [35]. Its a silver white, lustrous, dense, natural and commonly occurring weakly radioactive element. It is ubiquitous throughout the natural environment, being found in varying but small amounts in rocks, soils, water, air, plants, animals and in all human beings. On average, about 90 µg of uranium exist in the human body from normal intakes of food, water and air, approximately 66% is found in skeleton , 16 % in the liver, 8% in the kidneys and 10% in other tissues of the body. The average annual intake of uranium by adults had been estimated to be 460 µg from ingestion and from inhalation [4].

Uranium is widespread in nature, in a wide variety of solid, liquid and gaseous compounds. It readily combines with other elements to form uranium oxides, silicates, carbonates and hydroxides [37]. These compounds differ substantially in their chemical and physiological properties and in the toxicological effects they exert. Solubility of uranium varies depending on the

particular compounds and the solvent, and this solubility determines how quickly the body absorbed them from the lung and how efficiently the body absorbs them from the intestines [38,39].

2.3 Depleted Uranium

Depleted uranium (DU) is a toxic and radioactive by-product of the uranium enrichment process. Depleted uranium is considered a new source of radioactivity that introduced in the environment [40,41].

2.4 Properties of Depleted Uranium

2.4.1 Radiological Properties of Depleted Uranium.

Natural uranium consists of the isotopes ^{234}U, ^{235}U and ^{238}U of weight ratios 0.0055% , 0.71 % and 99.28 % respectively, in the naturally occurring uranium. These three isotopes posses half -lives of (2.5×10^5), (7.1×10^8) and (4.49×10^9) years, respectively [42].

Depleted uranium has the same three isotopes of natural uranium but in a different isotopic ratio from natural uranium. The content of ^{235}U isotope is reduced from (0.71 %) to (0.2 % -0.3 %) during the enrichment process [43], also the concentration of ^{234}U is to be around (0.005 % - 0.0020 %) consequently, depleted uranium has a higher percentage of ^{238}U (99.8 %) than naturally occurring uranium [37,44,30], so that depleted uranium is roughly 60 % as radioactive as naturally occurring uranium and it has a specific activity of (14.656) Bq/mg [43]. The comparison between natural uranium and depleted is presented in (Table 2-6) [43].

Table (2-5):- Isotopic composition of natural uranium and depleted uranium[43].

		U-234	U-235	U-238	Total
Natural Uranium	Weight %	0.0055 %	0.71 %	99.28 %	100 %
	Activity %	48.9 %	2.2 %	48.9 %	100 %
	Activity in 1g U_{nat}	12.356 Bq	0.568 Bq	12.356 Bq	25.280 Bq

		U-234	U-235	U-238	Total
Depleted Uranium	Weight %	0.00897 %	0.2 %	99. 8 %	100 %
	Activity %	14.2 %	1.1 %	84.7 %	100 %
	Activity in 1g U_{dep}	2.076 Bq	0.160 Bq	12.420 Bq	14.65 Bq

2.4.2 Chemical Properties of Depleted Uranium

Uranium is a heavy metal similar to tungsten, lead and cadmium. Unlike the radiological characteristics of an element, chemical characteristics of a heavy metal are independent of its isotopic form. All isotopes of uranium undergo the same chemical reactions in nature and possess identical physical characteristics such as melting point (1132.4C^{o}), boiling point (3818 C^{o}), ductility, and volatility [45].

Depleted uranium prossesses certain unique physical properties such as remarkable high density (19 g/cm^{3} twice the density of lead), pyrophoric nature, it may spontaneously ignite at room temperature in air, oxygen and water. At (200-400 C^{o}), uranium may spontaneously ignite in a carbon dioxide or nitrogen atmosphere [44].

The pyrophoric nature of depleted uranium is of special relevance to the health effects resulting from depleted uranium use in munitions and armor.

Both the impact of a depleted uranium penetrator on a target and the burning of depleted uranium produce depleted uranium dusts or aerosol particles. In addition to resulting in aerosol particles, when depleted uranium burns, the high temperature created act to oxidize uranium metal to a series of complex oxides, predominantly depleted triuranium octaoxide (U_3O_8), but also depleted uranium dioxide (UO_2) and depleted uranium trioxiode (UO_3). Upon weathering, the nonoxidized small particles and surfaces of remaining uranium metal will also slowly oxidize to those three depleted uranium oxides over time [37].

2.5 Exposure Pathways to Depleted Uranium

Exposure pathways are the routs by which radioactive material can reach man [46]. Depleted uranium like any other source of radiation can expose the individual. There are two such pathways: external and internal pathways.

2.5.1 External Exposure

People can be exposed to ionizing radiation from natural and man -made sources of ionizing radiation outside the body. Since 1991, when depleted uranium weapons were first used in conflict, exposure may occur to people working or living in areas where depleted uranium munitions were used and where they hit target and formed various oxides and uranium compound. Equipment contaminated with depleted uranium oxides can become a source of contamination when the oxides are re-suspended or otherwise dislodge during transit [37,47].

The danger of depleted uranium particulate and their radioactive daughter products such as thorium -234, protactinium -234 m, and other isotopes of uranium itself will continue to emit ionizing radiation (α ,β and γ) for decades to come [48].

2.5.2 Internal Exposure

When radioactive material such as depleted uranium inside the body they cause internal irradiation. Radioactive materials may be internally deposited in the body when an uptake occurs through one of the three routes of entry: inhalation, ingestion and skin contact. These exposures can occur when radioactive material is airborne, inhaled and absorbed by the lung and deposited in the body is present in contaminated food, drink or other consumable items and is ingested or is spilled or aerosolizes onto the skin and absorbed or enters through cuts or scratches. Internal deposition may also result from contaminated hands, with subsequent eating or rubbing of eyes [48].

Aerosols containing uranium are deposited on surfaces in the environment and can be re-suspended by the wind or human activities, which will result in an air contamination again. Uranium deposited on the soil can find its way in to the biosphere, thus contaminating drinking water, plants and animals belonging to the human food chain [37]. Figure (2-1) shows this pathway in more detail.

Origin of Depleted Uranium

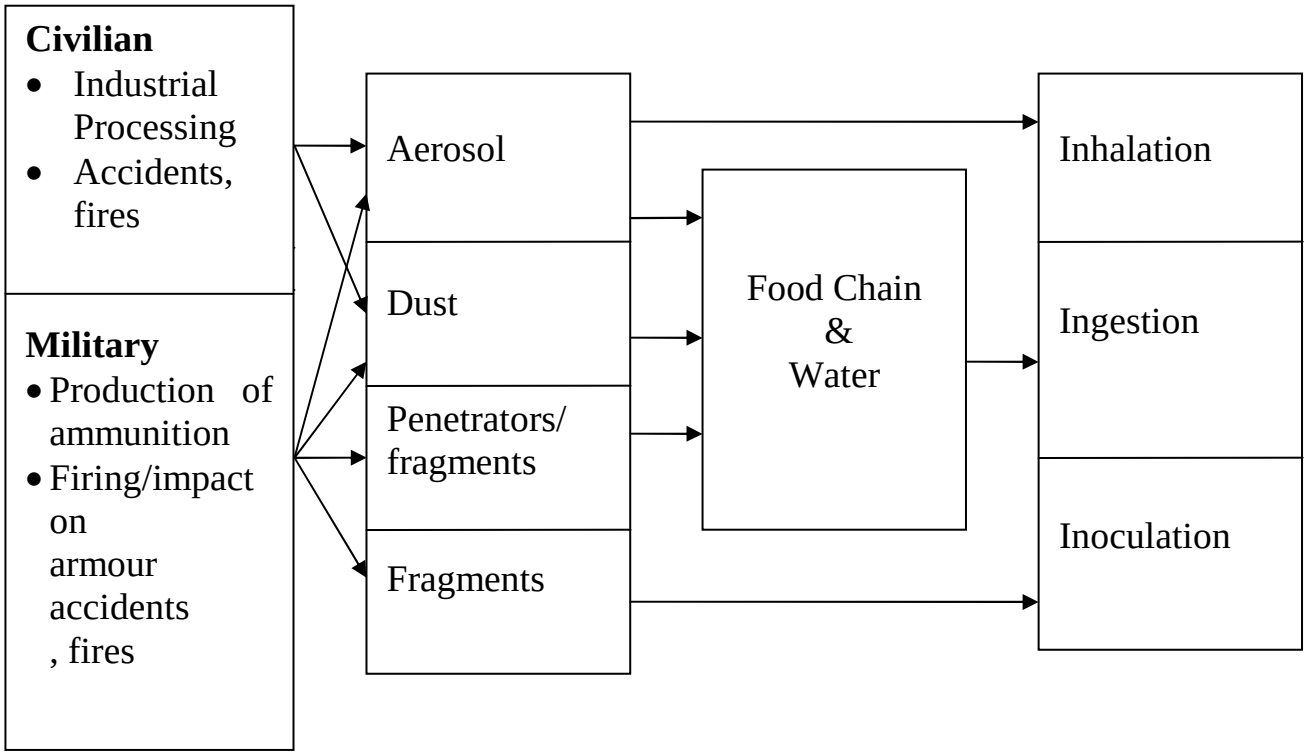


Figure (2-1):- Transfer pathways of depleted uranium in to the environment, reaching to man [47].

2.6 Behavior of Depleted Uranium Inside the Body

Absorption of inhaled uranium into the systemic circulation will depend on the rate at which the particle is dissolved in the lung and on their interactions with lung legend [43]. Soluble depleted uranium particles deposited in the lung usually dissolve, and the depleted uranium moves into the blood within days or weeks, while the insoluble particles tend to remain in the lung or lymph nodes for months or years [49، 38]. The soluble particles will be absorbed in the blood and remove from it to other organs where these particles accumulate [50،38]. Absorption through the gut depends upon the availability of various depleted uranium compounds to which an individual has been exposed [4].

After entry into the blood, uranium particles will be accumulated in the skeleton, so that this element calls "bone seeker" [51]. Small fraction of these particles will be distributed to the soft tissue such as kidney, liver, spleen, [52, 49, 51] and a substantial fraction rapidly excreted [35].

Uranium deposited in the bones and other organs is subsequently released back to the blood stream [53]. Clearance from the skeleton is considerably slower, half-lives of 300 and 5000 days have been estimated [52]. Biochemical processes cause the blood to reabsorb depleted uranium from the organs to start the process over [38]. The schematic presentation in figure (2-2) depicts how uranium interacts with the body. Inhaled, ingested or embedded fragments reach the blood after solubilizing either at the site of entry or at some other location in the body where they end up [43].

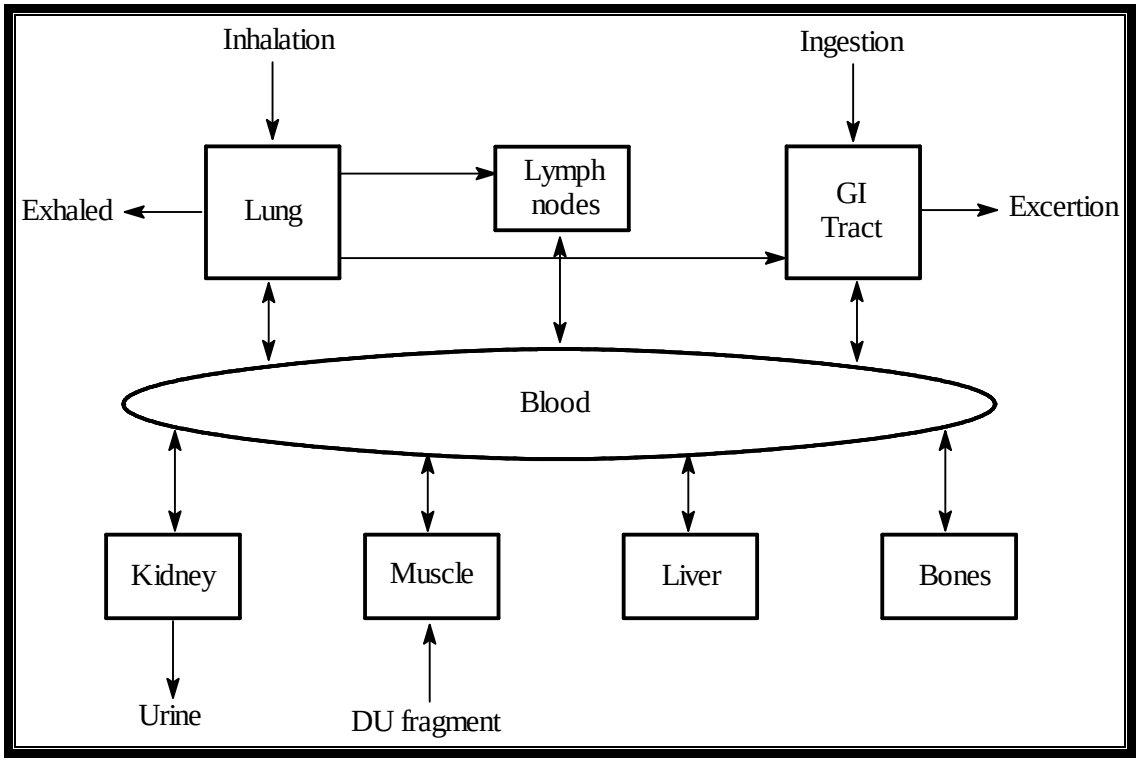


Figure (2-2) :- The schematic presentation of the behavior of DU inside the body [43].

2.7 How Can Uranium Enter and Leave the Body

Uranium enters the bodies through the food, water and air. When you breathe uranium dust, some of it is exhaled and some stays in lung. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves your body [24].

Uranium dust may consist of small, fine particles and coarse, big particles. The big particles are caught in the nose, sinuses, and upper part of the lung where they are blown out or pushed to the throat and swallowed. The small particles are inhaled down to the lower part of lung. If they do not dissolve easily, they stay there for many years and cause most of the radiation dose to lung from uranium; they may gradually dissolve and go into blood. If the particles do dissolve easily, they go into the blood more quickly [24].

A small part of the uranium swallowed will also go into the blood, and blood carries uranium through out the body. Most of it leaves in the urine in a few days, but a little stays in the kidney and bones. When eat food and drink liquids containing uranium, most of it leaves within a few days in the feces and never enters blood, a small portion will get into the blood and will leave the body through urine within a few days. The rest can stay in bones, kidney or other soft tissues; a small amount goes to the bones and may stay there for many years. Most people have a very small amount of uranium in the bodies, mainly in bones. Although uranium is weakly radioactive, most of the radiation it gives of cannot travel far from its source. If the uranium is out side the body, such as in soil, most of its radiation can penetrate skin and enter the body. If uranium transformation products are also present, you can be exposed to their radiation at a distance, as shown in figure (2-3) [45].

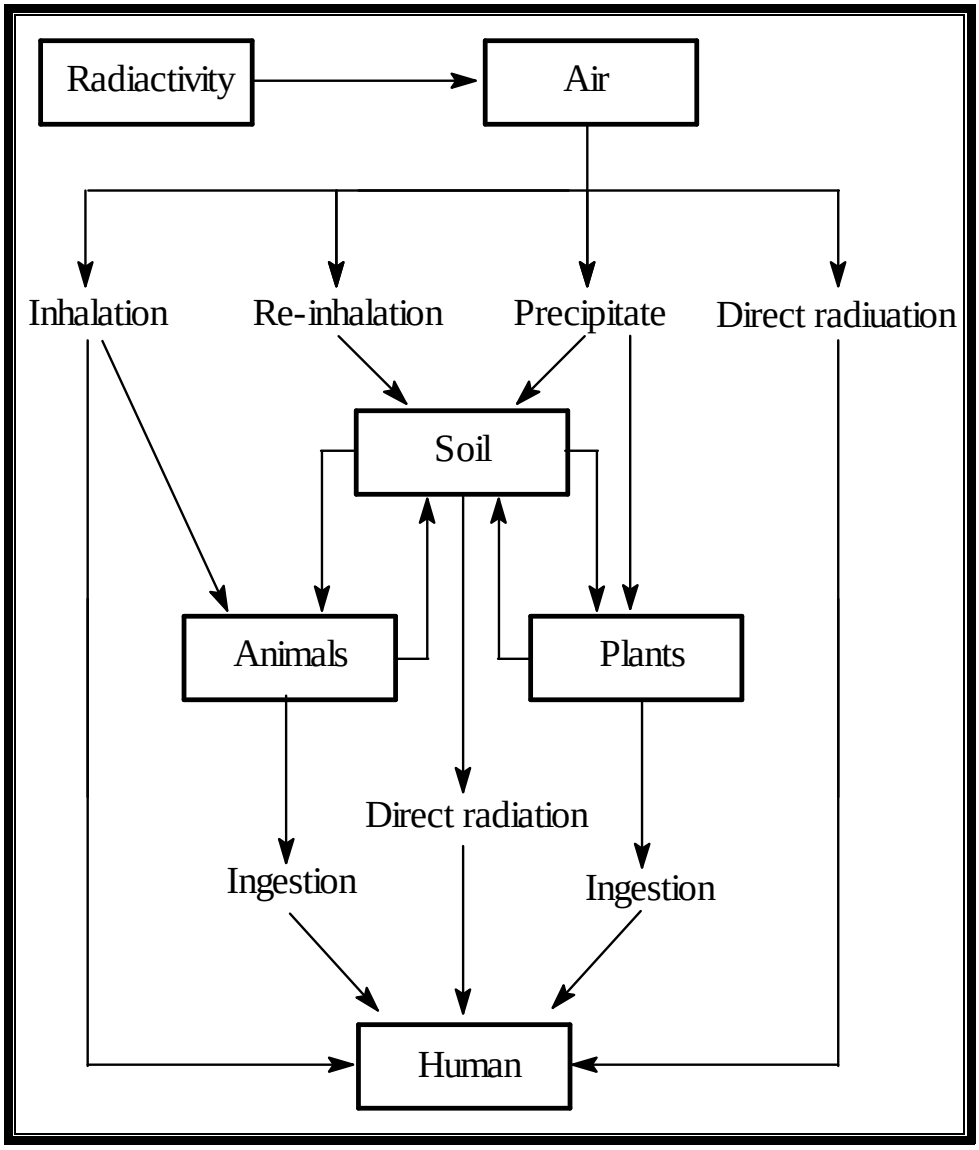


Figure (2-3):- Design translation radioactivity from air to human [54].

2.8 Health Effects of Depleted Uranium

If depleted uranium enters the body, it has the potential to generate significant medical consequences .The risks associated with depleted uranium in the body are both chemical and radiological [37]. Soluble uranium is regulated because of its chemical toxicity, while insoluble uranium is regulated by its radiological properties [39, 55].

2.8.1 Chemical Effects of Depleted Uranium

Uranium can be chemically toxic. Large amounts could enter and are retained in the body, absorbed into the blood and carried to body tissues, and organs. Once dissolved, uranium may react with biological molecules and exert its toxic effects [38].

According to researchers, the kidney is the organ most sensitivity to chemical effects from excess uranium. Depending on the concentration of uranium in the kidney, these toxic effects may include damage and death of kidney cells, decreasing the ability to filter impurities from the blood [30].

Soluble uranium, which is absorbed in the blood circulation within the body, is eliminated rapidly through the kidney in urine. About 67% are excreted within the first day without being deposited in any organ, approximately 11% is initially deposited in kidney and excreted with a 15-day half –life, most of the remaining 22% is initially deposited in the bone (up to 20%), which is the principle storage site in the body, and the rest is distributed to other organs and tissues [4].

2.8.2 Radiological Effects of Depleted Uranium

Depleted uranium emits ionizing radiation like alpha particles (α), beta particles (β) and gamma rays (γ), and its well known that all these types of ionizing radiation have biological effects on the living system.

α-particles will travel only about 30 μ m in soft tissue and, therefore, are unable to penetrate paper, glass, or even dead superficial layer of skin.

Beta particles have greater ability to penetrate the skin. In most circumstances, β-particle only presents a hazard if internalized. In contrast, γ- rays is extremely penetrating. As such, a γ- ray presents a hazard both internally and externally.

Depleted uranium emits alpha particles, which in direct physical contact, the insoluble parts of these particles enters the body of an exposed person, will

stay there and consequently ionize the body organ and the tissue surrounding it and causing different types of cancer [56]. Depleted uranium radioactivity cause several health problems ranging from cancer to kidney failure, respiratory disorders, congenital abnormalities, skin diseases, and other obscure unknown diseases [55, 57].

2.8.2.1 Mechanism of Ionizing Radiation Action

Ionizing radiation causes significant biologic effects with small amounts of localized energy that is powerful enough to break chemical bonds. It affects cells by direct ionization of molecules or, more commonly, by indirect ionization [58, 59].

A. Direct Action

This occurs when an ionizing radiation interacts with and is absorbed by macromolecule in a cell directly such as DNA [60].

These macromolecule become directly ionized in to free radicals as follows: [61].

$$RH \longrightarrow R^{\bullet} + H^{\bullet} \quad \text{..... (2-1)}$$

Where $R^{\bullet}$ Organic free radical

$H^{\bullet}$ free radical

Radiation induced modification of macromolecules, which can be divided in to two types:

(1) Structural Degradation and Decomposition

This phenomenon occurs in the macromolecules that consist of series of monomers, such as DNA, proteins, where these macromolecules broken to number of small molecules because of the breaks in the chemical bond

between them. These small molecules have the same chemical assembling of parent macromolecules [62].

(2) Cross-linking of molecules

All the long molecules have ability of folding so that could be cross-linked with each other and formed non- uniform solid forms [62].

Deoxyribonucleic acid (DNA) considers to be the most important target for ionizing radiation in the cell. The irradiation of DNA can be reflected in loss or modification of a base, sugar damage, breakage of hydrogen bonds between base pairs, strand breakage at sugar-phosphate bond, or cross-linking that can resulting in covalent bonding of two base within or between DNA molecules and protein [63,64,65].

B. Indirect Action

In the indirect action, radiation hits the water molecules, which is the major constituent of the cell (58%). When water is irradiated it is ionized producing a fast electron and positively charged water molecules: [66]

$$H_2O \longrightarrow H_2O^+ + e^- \quad \text{..... (2-2)}$$

This electron (e^-) will travel through the water until it is captured by another positive charged molecule :

$$H_2O^+ + e^- \longrightarrow H_2O \quad \text{..... (2-3)}$$

Neither H_2O^- or H_2O^+ is stable and each dissociates to give an ion and a free radical [61]:

$$H_2O^+ \longrightarrow H^+ + OH^\cdot \quad \text{..... (2-4)}$$

$$H_2O^- \longrightarrow H^\cdot + OH^- \quad \text{..... (2-5)}$$

Where, the dot indicates the unpaired electron of the free radical.

The final result of the radiolysis of water is therefore formation of a pair (H^+ and OH^-) and two free radicals ($H^\bullet$ and $OH^\bullet$). The ions can recombine, and therefore no biologic damage would occur. While the free radicals are charged particles having one or more unpaired electrons whose half- life are in the order of 10^{-17} s. They are chemically very reactive, and can set off a series of undesirable chemical reaction inside a living cell [28].

The $OH^\bullet$ free radical can join with a similar molecule and form hydrogen peroxide by the following equation [54]:-

$$OH^\bullet + OH^\bullet \longrightarrow H_2O_2 \quad \text{..... (2-6)}$$

Hydrogen peroxide is poisonous to the cell and therefore acts as a toxic agent.

The $H^\bullet$ free radical can interact with molecular oxygen if it is present to form the hydroperoxyl radical.

$$H^\bullet + O_2 \longrightarrow HO^\bullet_2 \quad \text{..... (2-7)}$$

The hydroperoxyl radical, along with hydrogen peroxide are considered to be the principle damaging products following the radiolysis of water [66].

2.8.2.2 Acute Effects (non-Stochastic Effects)

Acute effects or non-stochastic effects are induced by high radiation doses and the severity of the damages, rather than probability of occurrence, increases with the dose. These effects have a threshold dose below which no damage in evident. Cataracts, skin erythema (redness of skin) or epilation (loss of hair), sterility, blood component changes, fatigue, diarrhea, nausea and death are examples of deterministic effects induced by higher radiation doses [67].

2.8.2.3 Delayed Effects (Stochastic Effects)

Delayed or stochastic effects are the biological effects that occur randomly and for which the probability of effect occurring, rather than the severity, is assumed to be a liner function of the dose without threshold [48].

The delayed effects of radiation cause various syndromes long after the radiation exposure. The effects of irradiation for which there is no evidence of a threshold dose, somatic (such as cancer) and genetic (hereditary) diseases are endemic in all human population. The probability of occurrence for these types of diseases can be estimated using probability theory, if the probability of occurrence for a cancer or genetic disease increases in populations exposed to radiation, the increase is termed a stochastic health effect. Thus, an increase in the radiation exposure raises the probability of disease [66,60].

2.8.2.4 Somatic Effects of Ionizing Radiation

Somatic effects appear in the exposed person, where the somatic cells will be effected. Somatic mutations, either genetic or chromosomal, are not transmitted to the offspring of an exposed individual. However, increase in the frequency of these mutations may contribute to an increase in frequency of acquired disorders. Somatic effects are seen in the from of carcinogenesis, life shortening, cataractogenesis, and emberyologic damage [60].

The induction of cancer appears to be the most important effect of low-dose ionizing radiation to occur in an exposed population. Leukemia and thyroid, bone, breast, and lung cancers have been well documented in atomic bomb survivors, patients diagnostically exposed, industrial worker, scientists and physicians who were exposed during employment [48].

The excess risk of leukemia appears within a few years after radiation exposure and largely disappears within 30 years after exposure [68,48]. Solid cancers characteristically have long latent periods; they seldom appear before

10 years after radiation exposure and may continue to appear for 30 years or more after radiation exposure [48,60].

Thousands of people in Iraq have the same syndromes too. The incidence of cancer has increased rapidly and at are abnormal rate (Iraqi Cancer Board ,1991). Children in Iraq are reported to have a higher than normal incidence of malignancies and congenital malformations [69].The rise in the incidence rate of malignancies (specifically leukemia) among children below fifteen years of age in Basrah following the Gulf war has been well-documented [70,71].

Uranium compounds retained in the bone may cause malignant changes in the cells of the skeletal tissue, while (DU) retained in the respiratory tree may result in the induction of lung cancer [55].

2.8.2.5 Genetic Effects of Ionizing Radiation

Germinal cells are effected by ionizing radiation. A germline mutation, or inheritable genetic effects, occurs when the DNA of a reproductive cell (sperm or egg) is damaged. This called genetic mutation is defined as an alteration or change in the genetic material [72].

Genetic effects appear in the offspring of individuals exposed to ionizing radiation. If Genetic effects appear in the first generation of the irradiation individual , in which case the mutations are called dominant mutations, or those mutations that appear in the some later generation in this case they are called recessive mutations [73].

Radiation –induced gremlin mutation may cause health problems which include miscarriages, stillbirths, congenital defects, premature death (death in the first year of life), chromosomal abnormalities and cancer in later life [60].

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List of Symbols

Symbol	***Description***
SSNTDs	Solid state nuclear track detector
Am-Be	Americium- Beryllium Source
Bq	Becquerel
°C	Degree Centigrade
C_s	Uranium concentration of standard sample
C_x	Uranium concentration of unknown sample
d	diameter of the etch pit
DU	Depleted uranium
h	thickness of the surface removed by etching
IAEA	International Atomic Energy Agency
ICRP	International Committee of Radiation Protection
K	Boltzman constant = 1.38×10^{-23} j mol / k
L	length of latent track
n	neutron
N	Normality
NaOH	Sodium Hydroxide
ppm	part per millon
UNEP	United Nation Environmental Program
UNSCEAR	United Nation Scientific Committee on the Effects of Atomic Radiation
V_B	Bulk etch rate
V_T	Track etch rate
WHO	World Health Organization

ppb	Part per billon
a.m.u	Atomic mass units
θ_C	Critical angle
θ	Incident angle
η	Etching efficiency
ρ	Track Density
ρ_s	Track density of standard sample
ρ_x	Track density of unknown sample
μm	micrometer
μg	microgram
NCRP	National Council on Radiation Protection
AEPI	Army Environmental Policy Institute

References

[1] Whellock, "**General Biology**", Reginald Baldwin, London, Harrap,1974.

[2] Emmanuel C.B.," **Hematology; Introduction and Principles of Hematological Diagnosis** ", London, Sydney,1992.

[3] Berence M.R. & Veny M.," **Physiology** ", Sanders Company, 1987.

[4] World Health Organization, WHO, " **Depleted Uranium Sources, Exposure and Health Effects** ", 2001.

[5] http:// www.Anderson Cancer Center/ what is leukemia.htm.

[6] Harrias W.J.," **Red Cell** ", Harvard University, Press Cambridge , 1963.

[7] Diel B.K.L, " **Protins** ", AL-Mosal University, 1984.

[8] Beck S.W., " **Hematology** ", MIT Press, 1987.

[9] AL-Dargazelli SH.S., " **Detection of Nuclear Radiation; Health Physics Principles** ", Iraq, Baghdad University, **24**, June, 1987.

[10] http://www.Leukemia.htm.

[11] http://www.Leukemia /wikipedia /the free encyclopedia.htm.

[12] Picer M. & Strohal P., " **Determination of Thorium and Uranium in Biological Material** ", Anal. Chim. Acta., **40**, (1968),131.

[13] Hamilton E.I., " **Uranium Content of Normal Blood** ", Nature, **227**,(1970),501.

[14] Carpenter B.S. & Cheek C.H.," **Analytical Chemistry**" ,**42**, (1970), 121-123.

[15] Koul S.L. & Chadderton L.T.," **Uranium in Blood**", Rad.Eff., **50**, (1979) ,19.

[16] Parhad R. & Nagpaul K.K, **"Determination of Trace Content of Uranium in Normal Human Blood of Particle Track Etch Technique"**, Health Phys., **38**, (1980), 409.

[17] Romero M., Sanchez M. & Sanchez M. & Segovia N., **"Nuclear Tracks & Rad. Meas.** ",**8,** (1984), 457-459.

[18] Das K.C., Hanifa A. & Goswami T.D., **" Nuclear Tracks & Rad. Meas. ", 12**, (1986), 769- 792.

[19] Segovia N., Olguin M.E. & Romero M., **" Study of Uranium in the Blood of two Population Sample "**, Nuclear Tracks, **12,** 797,(1986), 1- 16.

[20] AL-Timimi W.A.K., **" Determination of Depleted Uranium Concentration in Biological Sample "**,M.Sc. Thesis, Al-Mustansiriyah University, 2000.

[21] Sultan M.F., **"Determination of Depleted Uranium in Blood "**, Iraq, Al-Mustansiriyah University, 2001.

[22] AL- Gailani A.W., **"Investigation of Biological Effects of Depleted Uranium on The Blood "**, Medicine College, Mustansiriyah University, 2003.

[23] Ibraheem M.F., **"Determination of Depleted Uranium Concentration in Leukemia Sample "**, Msc in Science of Physics, Al- Mustansiriyah University, 2003.

[24] Hassan S.F., **" Determination of Uranium Concentration in Human Blood in Some Governorates of Iraq "**, Msc in Science of Physics, Al- Nahrain University, 2006.

[25] United Nations Univronmental Program, UNEP, **" Radiation Doses, Effects and Risks** ", United Nations, 1985.

[26] Chapman N.A. & Mckinley I.G., **" The Geological Disposal of Nuclear Waste "**, Jonn Wiley and Sons, UK., 1987.

[27] United Nations Scientific Committee on The Effects of Atomic Radiation, UNSCEAR, " **Source, Effects and Risk of Ionizing Radiation** ", Report to the general Assembly with Scientific Annexes, United Nation, 1993.

[28] Brady J.E., Russell J.W. & Holum J.R., " **Chemistry: Matter and Its Changes** ", 3rd Ed. , USA, John Wieley and Sons, Inc., (2000), 1002-1008.

[29] Eisenbud M. & Gesell T., " **Environmental Radioactivity** ", 4th Ed., Academic Press, USA, 1997.

[30] Zajic V.S., " **Review of Radioactivity, Military Use and Health Effects of DepletedUranium**",1999.
http: // members . tripod.com / vzajic

[31] Chu T.C., Weng P.S. & Lin Y.M., " **Changes in Per Capita and Collective Dose Equivalent Due to Natural Radiation in Taiwan (1950-1983)** ", Health Physics, **156**, (1989) , 201-217.

[32] Clarke R.H., " **The Cause and Consequences of Human Exposure to Ionizing Radiation** ", Radiation Protection Dosim, **36**, (1991), 73-77.

[33] Friedlander G., Kennedy J.W. & Miller J.M., " **Nuclear and Radiochemistry** ", 2nd Ed., John Wiley and Sons Inc., 1964.

[34] International Commission on Radiological Protection, ICRP, "**Recommendations of The International Commission on Radiological Protection** ", Publication 26, Pergamon Press, Oxford and New York, **1**, No. 3, (1977).

[35] **The Environmental Behavior of Radium**, IAEA, Vienna, Technical Report Series, No. 310, (1990), 3-9, 11-54, 509-525, 89-204.

[36] Cartwright B.G., Shirk E.K. & Price P.B., " **Nucl. Inst. & Meth.** ", **153**, (1978), 457-460.

[37] Army Environmental Policy Institute, AEPI, " **Health and Environmental Consequences of Depleted Uranium Use in The U.S Army** ", Technical Report Atlanta, 1995.
http: // aepi. Gatech. Edu/ DU/

[38] Rostker B., Environmental Exposure Report, " **Depleted Uranium in The Gulf(II)** ", Office of The Seduced Assistant to The Secretary of Defense For Gulf War Illnesses, OSAGWI, Department of Defense, December, **13**, 2000.

[39] Bertell R., " **Gulf War Veterans and Depleted Uranium** ", In: Depleted Uranium: A Post-War Disaster For Environmental and Health, Laka Foundation, may, 1999.

[40] Fahey D.,**"Case Narrative Depleted Uranium Exposure** ", Swords to Plowshares, Inc. National Gulf War Resource Center, Inc., Military Toxices Project, Inc., 3rd Ed., Sep., **20**,1998. http: // www. du. Publica. ez/ papers/ Fahey. htm

[41] Marouf B.A., " **Environmental Impact of Depleted Uranium (DU) Contamination in Iraq** ", Proceeding of The Conference on The Effects of The Use of Depleted Uranium Weaponry on Human and Environmental in Iraq, Baghdad-Iraq, **1**, (2002), 116-122.

[42] **Analytical Techniques in Uranium Exploration and Ore Processing**, IAEA, Vienna, Technical Report Series, No. 341, (1992), 19-21.

[43] Harley N.H., Foulkes E.C., Hilborne L.H., Hudson A. & Antboy C.R., " **A Review of The Scientific Literature as it Pertains to Gulf War Illnesses** ", **7**, Depleted Uranium, RAND, National Defense Research Institute, Washington, USA,1999. http : // www.rand.org /publications/MR

[44] Dietz L.A., **"Contamination of Persian Gulf War Veterans and Other by Depleted Uranium** ",WISE, Uranium Project,June,Niskayuna,1999
http:// www.antenna.nl / wise/ uranium/

[45] Mc Graw-Hill, **" Mc Graw-Hill Encyclopedia of Sciences and Technology "**, 6th Ed., **19**, (1987), 75 -81.

[46] **International Basic Safety Standards for Protection Against Ionizing Radiation and for The Safety of Radiation Sources**, IAEA, Safety Series Report, No.115, (1994), 33-61.

[47] Keller M., Anet B., Burger M., Schmid E., Wlckl A. & Wirz C., **"Environmental and Health Effects of Depleted Uranium"**, SPIEZ, Laboratory, March, **31**, 2001
http://www.vbs.admin.ch/

[48] **Source and Effects of Ionizing Radiation**, UNSCEAR, New York, United Nation, (1993), 33-91.

[49] Muller H.L., Rossel E.D., Hotz G., Seidel A., Thiele H. & Pickering S.," **Behavior of Spherical and Irrigular (U,Pu)O_2 Particles After Inhalation or Intratracheal Instillation in Rat Lung & During in Vitro Culture with Boving alveolar macrophage** ", Int. J. Radia Biol., **55**, (1989), 829-842.

[50] Morris K.J., Khanna P. & Batchelor A.L., **"Long-term Clearance of Inhaled UO_2 Particles From The Pulmonary Region of The Rat "**, Health Physics, **58**(4), (1990), 477-485.

[51] Harley N.H. & Fisenne I.M., **" Distribution of Radiation Dose Naturally Occurring U, Th and Ra in The Human Skeleton"**, Heath Physics, **58** , (1990), 515-518.

[52] Kathren R.L., Mcinroy J.F., Moore R.H. & Dietert S.E., **"Uranium in Tissue of an Occupationally Exposed Individual ",** Heath Physics, **57**, (1989), 17-21.

[53] **Radionuclide releases into the environment: assessment of doses to man**, ICRP, Publication 29, Annals of the ICRP, 2(1), (1978), 1-50.

[54] **Agency for Toxic Substances and Disease Registry**, ATSDR, " Natural Uranium ", Atlanta, GA, U.S, Department of Health and Human Services, Public Health Services, 1999.

[55] Durakovi A., " **Medical Effects of Internal Contamination with Uranium** ", Department of Nuclear Medicine, George town University School of Medicine, Washington D.C., USA, No.1, **40**, 1999.

[56] Hoskens E., " **Depleted Uranium Shells Make the Desert Glow**", Depleted Uranium Education Project, Metal of Dishonor, International Action Center, New York, May, 1997.

[57] Aldicott H., "**Medical Consequences of Depleted Uranium**",2001. http:// www.stopnato.org.uk/du-wath/caldicott/medico.htm.

[58] Giancoli D.C., " **Physical Principles with Application** ", 5th Ed., Prentice Hall, Upper Saddle River, New Jersey, 2, (1998), 958-963.

[59] Atkins P. & Jones J., " **Chemical Principles, The Quest for Insight** ", New York, W.H. Freeman and Company, (1999), 810-812.

[60] Saha G.B., "**Physics and Radiobiology of Nuclear Medical**", 2nd Ed., New York, Spring-Werlag, Inc., (2001), 183-212.

[61] Coggel J.E., "**Biological Effects of Radiation**", 2nd Ed., London, Taylor & Francis Ltd., (1973), 12-20.

[62] Walden Th.L. & Farzeneh N.K., " **Biochemistry of Ionizing Radiation** ", USA, Raven Press Ltd., (1990), 36-49.

[63] Iwasaki S., Tanaka G. & Arima M., " **Effects of Prenatal X Irradiation on Chemical Components of DNA and DNA-Protein Crosslink in Rat Cerebrum in The Prenatal Periods** ", Rad.Res., **110** (1987), 72-83.

[64] Dizdaroglu M. & Simic M.G., **" Radiation-Induced Formation of Thymine- Thymine Crosslinks "**, Int. J. Radiat. Biol., **46**, (1984), 241-246.

[65] George A.M. & Camp W.A., **"The Effects of Ionizing Radiation on Structure and Function of DNA "**, Prog. Biophys. Molec. Biol., **50**, (1987), 121-169.

[66] Bushong S.C., **" Radiologic Science for Technologists: Physics, Biology and Protection"**, 5t Ed.,Mosby-Year Book, Inc., (1993), 125-200.

[67] **Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR v)**, Washing, Dc: National Academy Press, (1990), 327.

[68] **Ionizing Radiation Sources and Biology Effects**, UNSCEAR, New York, United Nation, (1988), 33-46.

[69] Cherian J., **" War Crimes of the West "**, Frontline**, 18**, 2001, 3-16.

[70] Yacoub A.H., Al-Sadoon I. & Hassan G., **" Depleted Uranium and Health of People in Basrah: An Epidemiological Evidence "**, The Medical Journal of Basrah University, **17**, (1999), 17-25.

[71] Yacoub A.H., Al-Sadoon I. & Hassan G., **" Futher Evidence on The Relation between Depleted Uranium and The Incidence of Malignancies Among Children in Basrah, Southern Iraq "**, The Medical Journal of Basrah University, **18**, (2000), 3-6.

[72] Ahluwalia K.B., **" Genetics "**, 5th Ed., India, New Age International (P) Limited, (1996), 261-281.

[73] Muller R.F. & Young I.D., **" Emery's Elements of medical Genetics "**, 10th Ed., USA, Harcourt brace and company limited, (1998), 75-100, 125-175.

[74] Hushemi S.R. & Durrani S.M., **" Nuclear Tracks "**, **3**, (1981), 189.

[75] Silk E.C.H. & Barnes R.S., " **Phil. Mag. ",4**, (1959), 970.

[76] Price P.B. & Walker R.M., " **Phy. Rev. Lett. ", 8**, (1969), 217.

[77] Price P.B. & Walker R.M., " **J. Appl. Phy. ", 33**, (1962), 2625.

[78] Fuji M. &Yokota R., " **Nuclear Tracks and Radiation Measurement ", 15**, (1990), 107.

[79] Fleischer R.L. & Price P. B., " **J. Appl. Phy. ", 34**, (1963), 2903.

[80] Fleischer R.L., Price P.B., Walker R.M., & Hubbard E.L., " **Phy. Rev. "**, 133A, (1964), 1443.

[81] Fleischer R.L., Price P.B. & Walker R.M., " **Ann. Rev. Nucl . Sci .", 15** ,(1965),15.

[82] Velickovic D., Miric I. & Bojoric P., " **Proceeding of the 11th Inter. Conf. on Solid State Nuclear Track Detector "**, Lyon, (1981), 583.

[83] Gohn C.E. & Golden R., " **Rev. Sci. Inst. ", 43**, (1972), 13.

[84] Monnin M.M., " **Nuclear Inst. and Meth. ",173**, (1980),1.

[85] Hepburn c.& Windle A.H., " **J. Material Science ", 15**, (1980), 279.

[86] Fleischer R.L., Price P.B. & Walker R.M., " **Nuclear Tracks in Solid "**, University of California Press, Berkeley, 1975.

[87] Enany N.E., Fiki S.A. & Husseiny H.E., " **Isotope & Rad. Res. ",**No.2, **26**, (1994), 91.

[88] Fleischer R.L. & Price P.B., " **Geochim Cosmochiam "**, Act. 28, (1964a), 1705.

[89] Fleischer R.L., Price P.B., Walker R.M. & Hubbard E.L., " **Criterion for Registration in Dielectric Track Detectors "**, Phys. Rev., **156**, (1967a), 353-355.

[90] Fleischer R.L., Price P.B. & Walker R.M., " **J.Apple.Phys. ", 36,** (1965), 45-52.

[91] Brinkman J.A., " **J. Apple. Phys."**, **25**, (1954), 961-970.

[92] Mohammed A.A., " **Polymer chemistry** ", (1993), Mosul Press, Iraq (In Arabic).

[93] Tager A.A., " **Physical Chemistry of Polymers** ", MIR Publication, Moscow, 1972.

[94] Laidler K.J. & Meiser J.N., " **Physical Chemistry** ", John Wiely & Sons. Inc. New York, USA, 1982.

[95] Durrani S.A., & Bull R.K., " Solid State Nuclear Detection; Principles, Methods and Applications ", Pergamon Press, U.K., 1987.

[96] Kobayashi T. & Fuji M., " **nuclear Tracks** ", **15**, 1988, 175.

[97] Nichulas T., " **Measurement and Detection of Radiation** ", Pergamon Press, University of Missouri-Rolla, U.K., 1987.