Distribution and uptake of uranium in rice and wheat from soil samples collected from Al- Diwaniyah, Iraq

Amer Y. Kadhim1,2, Khalid H. Al-Ataya1, Murtadha Sh. Aswood2

1Department of Physics, College of Science, University of Babylon. Babylon, Iraq
2Department of Physics, College of Education, University of Qadisiyah, Al-Diwaniyah, Iraq
sci.amer.hussein@uobabylon.edu.iq

Abstract. Wheat and rice are among the main ingredients on which the Iraqi populations depend. The important part of this is detected knowledge the uptake radionuclide in this cereal, no less in admiration of any personal health harmful. In this study, we measured the concentrations of naturally occurring radioactive nuclides in cereals and the corresponding soil collected from agricultural fields in Al Shamiyah, Al- Diwaniyah governorate in Iraq using nuclear detector of tracks (CR-39). The mean activity concentration of uranium (ppm) in soil, wheat and rice samples were found to be 1.18 ± 0.19, 0.02 ± 0.001 and 0.88 × 10^-2 ± 0.00085, respectively. Factors of transfer from soil-to- cereals were limited to be 0.012 and 0.017 for wheat and rice. The results of TFs of 238U were found to be in agreement with previous studies values, these results refer to radionuclides movement were very low in these soils. Results have been shown the uranium concentration to be less than permissible limit (11.7 ppm) proposed by UNSCEAR. On the other side, results noticed there are no pose significant threats to health of human, the edible cereals being safe to consume.

1. Introduction
The natural radiation is represented a part of human environment. Cosmic and cosmogenic radiation represented the main components of it. Terrestrial radiation is found in soil and rocks, and natural radioactive substances in the air we breathe and in our diet [1]. The environment take radionuclides as products or byproducts of nuclear technologies and as naturally occurring elements , uranium (U) is one of the most common radionuclides, it is very important isotopes amount under manage because all their so radioactive is dangerous[2]. Uranium is chemical and radioactive element, Symbolize it by (U), and it is a very high density (18.95 g /cm³, 1.7 times higher than lead’s density of 11.35 g /cm³) and a heavy metal [3]. Natural uranium consists of three isotopes, U-238 (99.276%), U-235 (0.718%) and U-234 (0.0056%) [4, 5]. Recently large number experiments were being doing for developing the sensitive plastic film of alpha particles (ASPF) group of the solid state nuclear detector (SSNTDs) for this purpose [6]. CR-39 is very important from the solid state nuclear detectors can be responded to particle of alpha with high efficiency [7]. One of the
most popular detectors used to study the natural damage product from heavily ionization radiation such as alpha particles or fission fragment. Nuclear track detector, in this technique of determined the number of particles by noticed its tracks in clear inorganic and organic materials was being used for studying of phenomena in such diverse fields as nuclear physics, geology, and astrophysics. This technique of this method based on, the damage predicted in a solid next to the pathway of heavy particle ionizing [8]. Transfer factor (TF) refers to the soil-to-plant, it called the ratio of concentration. It is defined the ratio between the concentration of activity in the dry weight of the plant and the concentration of activity in dry weight of the soil, all (in ppm) [9]. It is very important parameter used in studies for evaluating on the effect of normal and accidental release for radionuclides to environment and contamination level of agricultural grain. transfer factors from soil-to-plant change depending on characteristics for kind of soil, agricultural management (fertilization), the kind of crops, climatic condition of regional, chemical and physical, and formation of radionuclides in soil [10]. The grains are rich in nutrients, dietary fiber and carbohydrates [11] and also contain proteins, pectin, lipids, salts, and minerals [12, 13]. A number of studies have indicated the radioactivity concentration in soil and transfer factor of radionuclides from soil to grain (wheat and rice) [14-16]. This study work therefore, strives to evaluate and investigate the level of Uranium and TF for soil and grains in farmlands in Al-Shamiyah, Al-Diwaniyah in Iraq.

2. Experimental Part:

2.1. Study Area Description

A city of Al-Shamiyah part of Al-Diwaniyah Governorate, is located about (180 kilometers) from Baghdad - capital of Iraq, in the south it. Its area is (948) km² and the river -the Shatt al-Shamiyah- pass through it. It lies on coordinates (31.96 36 11°N, 44.59 88 89°E) [17]. In this study, the samples of soil and grain (wheat and rice) were collected from agricultural land samples in ten different villages from different regions as indicted in figure 1.

Figure1. Al-Diwaniyah Governorate and sites of sample [17].
2.2 Uranium Concentration
Fifty samples of soil and cereals (wheat and rice) have been taken from ten different locations from Al-Shamiyah, Al-Qadisiyah in republican of Iraq. All samples dried by expos for sun to achieve the condition of humidity for two days. Then the samples were heating to a temperature of 100°C by putting their in an electrical oven at for two hours. Then the samples were crushed into a fine powder and passed through a standard mesh size 75μ [18]. The resultant ash samples were mixed with methylcellulose (C₆H₁₀O₅) as a ratio of (0.5: 0.1 gm) which was used as a binder. The mixture was pressed into a pellet of 1 cm diameter and 1.5 mm thickness. These were put in contact with (CR – 39) detector in a plate of paraffin wax at a distance of (5 cm) from the neutron source as shown in Figure 2, with fluence of thermal neutron (3.024 × 10⁹ n.cm⁻²). After irradiation for 7 days, (CR –39) detectors were etched in (N = 6.25) NaOH solution at temperature of 60°C for 7 hours [18]. Etching process is applied after the irradiation of samples. This solution was prepared according to the following equation [19].

\[ C = \frac{W \times 1000}{W_{eq} \times V} \]

Where C is concentration of solution or normality, W is weight (25gm) of NaOH needed to prepare the given normality, Wₐq is equivalent weight of NaOH equal (40), and V: Volume of distilled water (100 ml).

Then, the detectors were washed completely in flowing cold water at room temperature for 10-20 minutes, then put in distilled water for 3 minutes to end the etching process [20], and dried in a fan. After that, the tracks densities of fission were recorded using Novel microscope with magnification of 400X. The track density was measured by the relationship mentioned in the following paragraph, as shown in figures 2-5.

Figure 2. Irradiation method to measure the concentration of uranium in blood and soil samples: (a) the samples were prepared to irradiation (b) neutron source.
Figure 3. Shows chemical etching

Figure 4. Shows the tracks of nuclear fission fragments in the detector (CR39)
Figure 5. Shows the tracks of alpha particles in the detector (CR39)

2.4 Curve of Calibration

The densities accumulated data of registered induced tracks of the standard samples was plotted as a function of concentration of uranium. The density of tracks of the blank detector of CR-39 was subtracted from all the determines. The curves of calibration of standard samples soil are given in figure (6) [21, 22].

![Curve of Calibration](image)

Figure 6. The relationship between track density and uranium concentration (ppm) of the standard soil samples

The calculation of uranium concentrations for soil and grain (wheat and rice) samples was carried out using comparing the track densities of the detectors for these samples with the track densities for the standard samples which was prepared in advance by[21,23]:

\[
\frac{C_s}{C_s} = \frac{\rho_s}{\rho_s}
\]
where $\rho_s$ and $\rho_x$ are densities of track for the study samples and standard samples (tracks/mm$^2$) and $C_s$ and $C_x$ are uranium concentrations of standard and unknown samples, respectively.

$$C_x = \left(\frac{C_s}{\rho_s}\right) \times \rho_x = \rho_s / \text{slope}$$

2.5. Transfer Factor

Transfer factor (TF), which is the ratio of consternation of nuclides in grains (wheat and rice) and soil (in ppm dry weight grains part divided by ppm dry weight soil), can be used as an guide of trace elements by grain or the shift of elements from soil to grain [24, 25].

The corresponding TF of different plants, relating the activity of a given radionuclide (U) for each individual plant were calculated for all vegetables as [26, 27]:

$$TF = \frac{\text{Grains concentration (ppm dry weight)}}{\text{Soil concentration (ppm dry weight)}}$$

3. Results and Discussion:

3.1. Uranium Concentration

The Tables 1 to 3 showed uranium concentrations in soil and grain (wheat and rice) samples respectively, of Al Shamiyah farmland measured by CR-39 detector reported in (ppm) on dry-weight basis. The results were indicated the highest concentration of uranium 1.39 ± 0.17ppm in Al-Hafar and the lowest concentration is 0.548 ± 0.106 ppm in Abo Kofoof and at the rate of this value for soil was 0.99 ± 0.13 ppm. As for wheat, the value of the highest concentration of uranium was 0.02 ± 0.0006 ppm in Al-Hafar. While, the lowest concentration was 0.009 ± 0.0007ppm in Al-Joboor, with an average value 0.017 ± 0.001ppm. On the other side of the rice, the highest concentration of uranium was 0.011 ± 0.001ppm in Nodaiba and the lowest concentration is 0.005 ± 0.0006 ppm in Al-Joboor, the average uranium concentration in rice was a value 0.0083 ± 0.0009 ppm. Results clarify that the concentrations of uranium in the study samples changed greatly with regard to the type of material concentrations of uranium. The samples found to be in arranging: soil > wheat > rice.

Uranium uptake from soil by plants depends on different connected properties of soil as clay content, texture, exchangeable cation, dominant clay minerals, content of organic matter, pH, and other conditions of environmental, as the reported of IAEA. In Table 4, the present results are determined for comparison with results from other countries. By comparing the results have shown the concentration of soil lower than the results in Brazil, Czech Republic, India, Kuwait and Baghdad and Basra in Iraq.

3.2. Soil-to-Grain (Wheat and Rice) Transfer Factors

Transfer factors for grain (wheat and rice) samples have been designed in the current study. TF is a useful parameter for radiological estimation and is defined as the steady state concentration between one physical situation and another, e.g., the ratio of concentration of an element in dry plant to that in dry soil [28]. Results have been shown in Tables 5 and 6, which the values of the uranium transfer factor between soil and wheat range between 0.0089 and 0.023. As for the uranium transfer factor between soil and rice, it ranges between 0.0051 and 0.019. Generally, TF of uranium from soil-to-grain is depends on soils, grain and locations.
The uptake of the isotope from soil by wheat and rice depends upon various interrelated soil properties, including texture, cation exchange capacity, exchangeable cations, pH, clay content, dominant clay minerals, and organic matter contents. It also varies depending on the chemical and physical forms of the radionuclides, plant species, and stage of growth.

Table 1. The uranium concentration in soil samples from agricultural lands in Al Shamiyah city

| S.C. | Reg.       | Cons.(U/ppm) | Av. Cons.(U/ppm) |
|------|------------|--------------|-----------------|
|      | S01 Al-Joboor | 1.17 1.33 1.46 0.30 1.11 | 1.07 ± 0.06 |
|      | S06 Abo Kofoof | 0.36 0.56 0.70 0.66 0.46 | 0.55 ± 0.11 |
|      | S11 Al-Hadadi | 0.90 0.72 1.51 0.59 1.97 | 1.14 ± 0.05 |
|      | S16 Tabar Zaweed | 0.84 0.24 1.54 1.30 0.64 | 0.91 ± 0.12 |
|      | S21 Al-Filahi | 0.28 0.83 1.21 0.82 1.37 | 0.90 ± 0.16 |
|      | S26 Al-Chalakh | 0.97 0.91 0.81 1.42 0.55 | 0.93 ± 0.21 |
|      | S31 Al-Najaria | 0.53 0.68 0.59 1.89 0.38 | 0.81 ± 0.06 |
|      | S36 Al-Giratia | 0.81 1.39 1.54 1.65 1.18 | 1.31 ± 0.27 |
|      | S41 Al-Hafar | 1.10 1.44 1.55 1.72 1.14 | 1.39 ± 0.17 |
|      | S46 Nodaiba | 0.56 0.9 1.25 1.78 0.38 | 0.97 ± 0.11 |
|      | Av. | | 0.99 ± 0.13 |

Table 2. The uranium concentration in wheat samples from agricultural lands in Al Shamiyah city

| S.C. | Reg.       | Cons.(U/ppm) | Av. Cons.(U/ppm) |
|------|------------|--------------|-----------------|
|      | W01 Al-Joboor | 0.006 0.016 0.007 0.004 0.01 | 0.009 ± 0.0008 |
|      | W06 Abo Kofoof | 0.011 0.011 0.006 0.008 0.008 | 0.044 ± 0.0008 |
|      | W11 Al-Hadadi | 0.017 0.019 0.015 0.013 0.014 | 0.016 ± 0.0015 |
|      | W16 Tabar Zaweed | 0.009 0.017 0.009 0.018 0.009 | 0.012 ± 0.001 |
|      | W21 Al-Filahi | 0.019 0.007 0.011 0.017 0.013 | 0.013 ± 0.001 |
|      | W26 Al-Chalakh | 0.017 0.01 0.018 0.013 0.006 | 0.013 ± 0.0015 |
|      | W31 Al-Najaria | 0.007 0.017 0.015 0.007 0.016 | 0.012 ± 0.0007 |
|      | W36 Al-Giratia | 0.016 0.016 0.016 0.016 0.015 | 0.016 ± 0.0008 |
|      | W41 Al-Hafar | 0.024 0.018 0.014 0.016 0.013 | 0.017 ± 0.0006 |
Table 3. The uranium concentration in rice samples from agricultural lands in Al Shamiyah city

| S.C. | Reg.       | Cons.(U/ppm) | Av. Cons.(U/ppm) |
|------|------------|--------------|------------------|
|      |            | 1  | 2     | 3     | 4     | 5     |
| R01  | Al-Joboor  | 0.002 | 0.003 | 0.007 | 0.005 | 0.009 | 0.005 ± 0.0006 |
| R06  | Abo Kofoof | 0.007 | 0.017 | 0.014 | 0.003 | 0.009 | 0.01 ± 0.00098 |
| R11  | Al-Hadadi  | 0.005 | 0.005 | 0.012 | 0.017 | 0.011 | 0.01 ± 0.0009 |
| R16  | Tabar Zaweed | 0.003 | 0.012 | 0.005 | 0.012 | 0.016 | 0.009 ± 0.0008 |
| R21  | Al-Filahi  | 0.007 | 0.006 | 0.009 | 0.005 | 0.008 | 0.007 ± 0.0008 |
| R26  | Al-Chalakh | 0.003 | 0.007 | 0.008 | 0.007 | 0.007 | 0.006 ± 0.0007 |
| R31  | Al-Najaria | 0.008 | 0.008 | 0.008 | 0.008 | 0.012 | 0.009 ± 0.0009 |
| R36  | Al-Giratia | 0.008 | 0.004 | 0.007 | 0.016 | 0.007 | 0.008 ± 0.0009 |
| R41  | Al-Hafar   | 0.007 | 0.007 | 0.009 | 0.008 | 0.004 | 0.007 ± 0.0008 |
| R46  | Nodaiba    | 0.009 | 0.006 | 0.014 | 0.008 | 0.015 | 0.011 ± 0.001 |
| Av.  |            |     | 0.0168 ± 0.0011 |

Table 4: A compared Uranium concentration with the values reported in other countries.

| Country          | C_U (ppm) for Soil | References |
|------------------|--------------------|------------|
| Brazil           | 0.001-2.12         | [29]       |
| Czech Republic   | 2.4                | [30]       |
| India            | 0.24-9.2          | [31]       |
| Kuwait           | 0.30-1.85          | [32]       |
| Earth Crust      | 2.5                | [33]       |
| Baghdad City     | 3.82               | [34]       |
| Basra (Qurna)    | 16.1               | [34]       |
| UNSCEAR          | 11.7               | [33]       |
| Al-Shirtiyah     | 0.99               | Present study|

Table 5. TF of uranium concentration from soil to wheat samples from agricultural lands in Al Shamiyah city

| Reg.            | Transfer Factor | Average |
|-----------------|-----------------|---------|
|                 | 1  | 2   | 3   | 4  | 5  |
| Al-Joboor       | 0.0052 | 0.012 | 0.005 | 0.013 | 0.0091 | 0.0089 |
| Abo Kofoof      | 0.031 | 0.0197 | 0.0086 | 0.012 | 0.0174 | 0.0177 |


| Reg.        | Transfer Factor | Average |
|-------------|-----------------|---------|
| AlJoboor    | 0.0017          | 0.0023  | 0.0048  | 0.0167  | 0.008  | 0.0067  |
| Abo Kofoof  | 0.0194          | 0.0304  | 0.0201  | 0.0045  | 0.0196 | 0.0189  |
| AlHadadi    | 0.0036          | 0.0069  | 0.0079  | 0.0288  | 0.0056 | 0.0109  |
| Tabar Zaweed| 0.0250          | 0.0072  | 0.0075  | 0.0061  | 0.0059 | 0.0103  |
| AlFilahi    | 0.0031          | 0.0077  | 0.0099  | 0.0049  | 0.0127 | 0.0077  |
| AlChalakh   | 0.0015          | 0.0118  | 0.0136  | 0.0042  | 0.0216 | 0.0152  |
| AlNajaria   | 0.0099          | 0.0029  | 0.0046  | 0.0097  | 0.0059 | 0.0066  |
| AlGiratia   | 0.0064          | 0.0049  | 0.0059  | 0.0047  | 0.0035 | 0.0051  |
| Nodaiba     | 0.0161          | 0.0067  | 0.011   | 0.0045  | 0.0395 | 0.0156  |

Average: 0.0174

### Table 6. The transfer factor of uranium concentration from soil to rice samples from agricultural lands Al Shamiyah city

4. Conclusions

The uranium concentrations of soil, grain (wheat and rice), and the transfer factors for soil-to-grain (wheat and rice) were calculated for samples collected from of in Al- Shamiyah, Iraq. Present studies have been shown the uranium concentrations of the soil diverse with respect to type of soil, position, and geological formation of the region in this study. However, the results in this study clarify that consumption of the grain pointing to no serious health notification to the people. Since the maximum uranium concentration in the environment is undesirable, continuous monitoring should be undertaken to detect the uranium concentration in soil, grain and soil-to-grain. The results of transfer factor of uranium have been noticed the TF of soil to rice is higher than the TF of soil to wheat, perhaps this is due to the time period for cultivation and the amount of water and fertilizers.

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References
[1] Bochicchio F, McLaughling J and Piermattei S 1995 Radon in indoor air, (European Collaborative Action), Report No. 15, p. 50.
[2] Todorov P and Ileva E N 2006 Contamination with uranium from natural and anthropological sources, Rom. Journ. Phys., Vol.51(1-2), (27-34).
[3] Fleischer R L., P. B. Price and R.M. Walker 1975 Nuclear Tracks in Solids Principles and Applications. (Berkeley, USA, University of California Press).
[4] M. A. Misdaq and H. Ouabi 2006 238U and 232Th concentrations in various potable waters in Morocco, J. of Rad. Analy. Nucl. Chem., Vol.270(3), (543-553).
[5] R. E. White, 2013, Principles and practice of soil science: the soil as a natural resource. (John Wiley & Sons).
[6] Aswood M S, Abojassim A A and Al Musawi M S 2019 Natural radioactivity measurements of frozen red meat samples consumed in Iraq. Radiation Detection Technology and Methods 1;3(4):57.
[7] Makhijani A, Chalmers L and Smith B 2004 Uranium enrichment: Just plain facts to fuel an informed debate on nuclear proliferation and nuclear power Institute for Energy and Environmental Research, Vol.15.
[8] Gavrilescu M. L, Pavel V and Cretescu I 2009 Characterization and remediation of soils contaminated with uranium, Journal of Hazardous Materials, Vol.163 (2) (475-510).
[9] Abu-Khadr A S, Eissa H S 2008 IX radiation physics & protection conference. Nasr city - Cairo, National Networkof Radiation Physics-Egyptian Atomic Energy Authority 239-249.
[10] Shanthia G, Kumaranb J T T, G. Rajc A G, Maniyand C G 2013 Pelagia Research Library Advances in applied science research 4 (4): 283-287.
[11] Ghnimi S, Umer S, Karim A, and Kamal-Eldin A 2017 Date fruit (Phoenix dactylifera L.): an underutilized food seeking industrial valorization NFS J 6:1–10.
[12] Karizaki V M 2017 Iranian dates and ethnic date-based products. J EthnicFoods 4:204–209.
[13] Baliga M S, Baliga BRV, Kandathil S M, Bhat H P and Vayali P K 2011A review of the chemistry and pharmacology of the date fruits (Phoenix dactylifera L.). Food Res Internat 44:1812–1822.
[14] Kritisananuwat R, Chanyotha S, Kranrod C. and Pengvanich P 2017 Transfer factor of 226Ra, 232Th and 40K from soil to Alpinia Galangal plant grown in northern Thailand, IOP Conf. Series: Journal of Physics: Conf. Series 860.
[15] Ilemona C, Okemea V, Iyeh Suleb, N, Norbert Jibiric and Hammed O 2016 Radioactivity Concentrations in Soil and Transfer Factors of Radionuclides (40K, 226Ra and 232Th) from Soil to rice in Kogi state, Nigeria, Archives of Applied Science Research 8 (6):34-38.
[16] Nidhala H K and Saja S K 2018 Measurement of Uranium Concentration in Some Soil Samples in Tuwaitha site in Baghdad using CR-39 Detector, International Journal of Current Engineering and Technology INPRESSCO® All Rights Reserved.1-10.
[17] Amer Y K Khalid H A and Muratdha Sh. A 2020 Distribution of Radon Concentration in Farmland Soil Samples in Al-Shamiyah City, Al-Qadisiyah, Iraq IOP: Conf. Ser. 1591 012089
[18] Aswood M S, Jaafar M S, and Bauk S 2013 Assessment of radionuclide transfer from soil to vegetables in farms from Cameron Highlands and Penang,(Malaysia) using neutron activation analysis. *Applied Physics Research* **1**(5):85.
[19] Gudowska I, Sobolevsky N, Andreo P, Belkic D, and Brahme A 2004 Ion beam transport in tissue-like media using the Monte Carlo code *SHIELD-HIT Physics in Medicine and Biology* **49**(10): 1933.
[20] Gil A N and Kilee J 2005 Construction of An Environmental Radon Monitoring System Using CR-39 Nuclear Track Detectors. *Nuclear Engineering and Technology* **37**(4): 395-340.
[21] Al-Hamzawi A A 2015 Study of uranium concentration and toxic elements in biological samples of cancerous patients in Southern Iraq PhD Thesis, *College of school of physic Malaysia University*.
[22] Al-Baidhani M A 2006 Determination of the radioactivity in soil and water in Baghdad, Karbala and Basrah samples MSc. Thesis, *Al-Nahrain University College of Science*.
[23] Tawfiq N F, Al-Jobort S M, Al-Saji A W and Itawi R K 2002 Determination of alpha-emitters in Iraqi soil samples using solid state nuclear track detectors CR-39 and CN-85. *The Conference on the Effects of DU Weaponry on Human and Environment in Iraq*.
[24] Whicker F W, Hinton T G, Orlandini K A and Clark S B 1999 Uptake of Natural and Anthropogenic Actinides in Vegetable Crops Grown on a Contaminated Lake Bed *Journal of Environmental Radioactivity*, Vol. **45** pp. 1-12.
[25] Mollah A S 2014 Radionuclide uptake from soil to plants: Influence of soil classification Radionuclide contamination and remediation through plants vol I ed D K Gupta and C Walther (Switzerland: Springer).
[26] International Atomic Energy Agency 2009 Quantification of radionuclide transfer in terrestrial and freshwater environments for radiological assessments (IAEA-TECDOC-1616) *Vienna International Atomic Energy Agency*.
[27] James J P, Dileep B N, Ravi P M, Joshi R M , Ajith T L, Hegde A G and Sarkar P K 2011 Soil to leaf transfer factor for the radionuclides 226Ra, 40K, 137Cs and 90Sr at Kaiga region, India J. Environ. Radioact. **102**(12) 1070-7.
[28] Salih N F, Aswood M S and Hamzawi A A 2019 Effect of porosity on evaluation of radon concentration in soil samples collected from Sulaymania governorate, Iraq In *Journal of Physics: Conference Series IOP* **1234**(1) 012024.
[29] Perez D V, Saldanha M F D, Moreira J C. and Vaitsman D S 1998 Total concentration of uranium and thorium in some Brazilian soils. *Pesquisa Agropecuaria Brasileira* **33**(8), 1417–1423.
[30] Ledvina R, Kolar L and Frana J 1996 Uranium, thorium ,and other elements in topsoils of the Trebon region from the aspect of production contamination. *Rostlinna Vyroba*, Vol.42 Issues.2 pp 73–78.
[31] Singh A K, Kumar A, Jojo P J and Prasad R 1998 Microanalyses of uranium in Indian soil samples using solid state nuclear track detection technique. *Journal of Radioanalytical and Nuclear Chemistry* Vol.**238** Issue.1–2 pp.21–24.
[32] Bou–Rabee, 1995 Estimating the concentration of Uranium in some environmental samples in Kuwait after the 1991 Gulf War Applied Radiation Isotopes vol.**46** pp.217–220.
[33] UNSCEAR2000: Exposures from natural radiation sources. UNSCEAR 2000 Report to the General Assembly, with scientific annexes. United Nations, New York: United Nations Scientific Committee on the Effects of Atomic Radiation.
[34] Fadil N T, Abdullah N H and Bedin S A 2011 Measurement of Uranium Concentration in Soil of Middle of Iraq using CR – 39 Track Detector *Baghdad Journal for science* vol.**2**, pp. 451-455.