Investigation of uranium concentrations in selected soil samples of Al-Diwaniyah governorate, Iraq using CR-39 detector

Majied G. Al-Gharabi1, Anees A. Al-Hamzawi1*

1Department of Physics, College of Education, University of Al-Qadisiyah, Diwaniyah-Iraq
*E-mail: aneesphys@gmail.com; anees.hassan@qu.edu.iq

Abstract. In the present investigation, neutron activation technique for nuclear track detectors CR-39 has been applied to determine the uranium concentration in selected soil samples collected from different areas residential, industrial and agricultural of Al-Diwaniyah governorate southern Iraq, with various depths of soil (0, 10, 20, 30 and 40 cm), respectively. The results show that the uranium contents in soil samples ranged from 3.66 ± 0.13 ppm to 0.71 ± 0.16 ppm, with an average value of 2.1 ± 0.12 ppm. Results of this work showed a decrease of uranium concentration with increased depth of soil. The results were compared with the published data and they were found to be within the safety levels.

1. Introduction
Uranium is a silvery, shiny metal and is a long-lived natural radionuclide. Uranium is the heaviest natural element. It is one of the most serious contamination concerns result of its radioactivity. Uranium and its products are highly toxic, which is a threat to human health and environmental balance [1 – 3]. Uranium is one of the most widespread elements in nature, and it exists in the form of solid, liquid, and gaseous compounds. It exists in soil, rocks, natural materials, food, water and air. Uranium readily combines with other elements to form uranium oxide, silicates, hydroxides and carbonates [2, 4]. Uranium is found in three radioactive isotopes 238 U, 235 U and 234 U with a relative abundance by mass 99.27%, 0.72% and 0.0054%, respectively [5]. The physiological behavior of uranium compounds depends mainly on their solubility. Soluble uranium is regulated because of its chemical toxicity, while insoluble (less soluble) uranium is regulated by its radiological properties. But because of its slow absorption through the lungs and the long retention time in the body tissues, its primary damage will be to its radiological damage (risk of cancer death) to internal organs rather than the risk of significant chemical damage to the renal system [6]. Uranium can reach into the human body through different ways. It enters the body in a direct way by inhaling uranium-bearing dust particles or by drinking water which is polluted by uranium, or in an indirect way from the fertile soil layer via the food chain [1, 7]. Fission track analysis FTA with CR-39 detector is more efficient to determine the trace concentrations of uranium in geological and biological samples [1, 2, 8]. Many researchers studied the concentration of uranium in the soil samples because of the importance of the subject and its impact on the environment and health of people [9 – 12]. The aim of this study is to determine the uranium concentration in selected soil samples collected from different areas residential,
industrial and agricultural of Al-Diwaniyah governorate southern Iraq, using neutron activation technique for nuclear track detectors CR-39. Al-Diwaniyah governorate has a total area of 8,153 km² and the population was estimated to be 1,320,000 people. It is situated on longitude of 44 degree and 92 minutes east, latitude of 31 degree and 98 minutes north [13]. This study was conducted in the governorate of Al-Diwaniyah due to the absence of a previous study and the establishment of a database on the level of uranium concentrations in soil samples.

2. Material and method

2.1. Sample collection

In this study, 100 soil samples were collected from 20 different area of Al-Diwaniyah governorate southern Iraq, with 5 samples of each area as shown in Figure 1. The soil samples were collected from different depths of soil (0, 10, 20, 30 and 40) cm, respectively. The study areas varied in nature, which included residential, agricultural and industrial areas Table1. About 20 g of soil samples, which are sufficient for getting the required amount for fission track analysis technique, the samples were cleaned and stones, pebbles, and root parts were removed. The samples were stored in plastic vials with the code of the sample.

2.2. Experimental method

The uranium concentration in soil samples was determined by using FTA with sensitive solid nuclear track detector (CR-39, Pershore Moulding Ltd, UK). The soil samples were heated at 100 °C for 2 h using an electric oven to dry, and then they were grinded using an agate mortar. The powder soil of (0.5 g) were mixed with (0.1 g) of methylcellulose which is used as a binder. The mixture was compressed as a pellet by a manual piston with a diameter of (1 cm) and a thickness of (1.5 mm). The pellets were covered with CR-39 track detector its dimension (1×1 cm) on both sides. Then, the irradiation process was performed, where the pellets placed in a dish of paraffin wax at a distance of 5 cm from the neutron source (Am-Be) with a thermal flounce equal to (3.024 × 10⁹ n cm⁻²) for 7 days, to cause latent damage on the detector due to the reaction of $^{235}$U (n, f). After the irradiation process, the chemical etching of detectors was performed under controlled conditions in (NaOH) solution as reported elsewhere [1, 14]. The induced fission tracks densities were recorded using optical microscope (Meiji, Japan) with magnification of 400×, the microscope was connected with an optical camera to observe the tracks. Fission track density ($\rho$) was measured by divided the average of tracks to the area of field view as given by Al-Hamzawi [1].

$$\text{Track density (}\rho\text{)} = \frac{\text{average of tracks}}{\text{area of field view}} \quad (1)$$

2.3. Calculation

The investigation of uranium concentration in the soil samples was carried out by comparison between track densities registered on the detector of soil samples and that of the standard samples by using the equation as reported elsewhere [1, 2].

$$U_x = U_s \left( \frac{\rho_x}{\rho_s} \right) \quad (2)$$

Where $\rho_x$ and $\rho_s$ are the induced fission track density for unknown sample and standard sample in (tracks/mm²), $U_x$ and $U_s$ are the uranium concentrations in unknown sample and standard samples in (ppm).
The mean value of uranium concentrations in soil samples is 1.84 ± 0.11 ppm. The maximum value of uranium ranged from 0.66 ± 0.10 ppm found in sample S18 to 3.38 ± 0.11 ppm found in sample S13, with a mean value of uranium concentration in soil samples at depth 10 cm of 2.8 ppm reported by [15]. The mean value of uranium content in the surface soil samples of Al-Diwaniyah governorate is within the acceptable level of uranium 2.12 ± 0.12 ppm. The mean value of uranium concentration is 0.71 ± 0.16 ppm found in sample S18 which belongs to Niffur city, with a value of 2.8 ppm reported by [15]. The analysis results obtained from the soil samples are involved in this study and are shown in Table 3.

### Table 1. Demographic information of the study areas in Al-Diwaniyah governorate

| Name of area                  | Sample code | Coordinates | Area classification                  |
|------------------------------|-------------|-------------|--------------------------------------|
| Al-Furat district            | S1          | 32°.03 N, 44°.89 E | Industrial – Electrical power plant   |
| Al-Thaqlin district          | S2          | 31°.96 N, 44°.95 E | Industrial – Factory of plastic and fabric |
| Al-Askari district           | S3          | 31°.99 N, 44°.94 E | Residential                           |
| Al-Wahda district            | S4          | 31°.99 N, 44°.95 E | Residential – Main road and traffic jam |
| Al-Jameih district           | S5          | 31°.97 N, 44°.95 E | Agricultural                          |
| Al-Nahda district            | S6          | 31°.98 N, 44°.95 E | Residential                           |
| Al-Sinaei district           | S7          | 31°.98 N, 44°.89 E | Industrial – Car repair garage        |
| Al-Jamieh district           | S8          | 31°.99 N, 44°.87 E | Residential                           |
| Al-Taamim district           | S9          | 31°.98 N, 44°.93 E | Residential – Main road and traffic jam |
| Al-Adiaryuh district         | S10         | 31°.98 N, 44°.91 E | Agricultural                          |
| Al-Dagharah city             | S11         | 32°.06 N, 44°.77 E | Agricultural                          |
| Al-Saniya city               | S12         | 32°.07 N, 44°.77 E | Agricultural                          |
| Al-Hamad village             | S13         | 31°.99 N, 44°.97 E | Industrial – Electrical power plant   |
| Afak city (Al-Rasul district) | S14         | 32°.03 N, 45°.14 E | Industrial – Car repair garage        |
| Afak city (Or district)      | S15         | 32°.04 N, 45°.18 E | Residential                           |
| Afak city (Al-Shurta district)| S16         | 32°.06 N, 45°.24 E | Residential                           |
| Sumer city                   | S17         | 32°.14 N, 44°.99 E | Agricultural                          |
| Niffur city                  | S18         | 32°.12 N, 45°.23 E | Residential                           |
| Al-Hamza city                | S19         | 31°.73 N, 45°.00 E | Residential                           |
| Al-Sahmiya city              | S20         | 31°.97 N, 44°.69 E | Industrial – Electrical power plant   |

### 3. Results and discussion

The analytical results obtained from the soil samples are involved in this study and are shown in Table 2. From this table, the highest value of uranium concentration in surface soil sample at depth (0 cm) is 3.66 ± 0.13 ppm found in sample S13 which belongs to Al-Hamad village, while the lowest value of uranium concentration is 0.71 ± 0.16 ppm found in sample S18 which belongs to Niffur city, with a mean value of uranium concentration in the surface soil samples is 2.12 ± 0.12 ppm. The mean value of uranium content in the surface soil samples of Al-Diwaniyah governorate is within the acceptable level of uranium 2.8 ppm reported by [15]. The uranium concentration in soil samples at depth 10 cm ranged from 0.66 ± 0.10 ppm found in sample S18 to 3.38 ± 0.11 ppm found in sample S13, with a mean value of uranium concentrations in soil samples is 1.84 ± 0.11 ppm. The maximum value of
uranium concentrations that obtained at depth 20 cm is 3.31 ± 0.11 ppm which belongs to Al-Hamad village, whereas the minimum value of uranium content in soil samples is 0.41 ± 0.05 ppm which belongs to Niffur city, with a mean value of uranium content is 1.64 ± 0.12 ppm. As regard to concentrations of uranium in soil samples at depth 30 cm, the value ranged between 0.37 ± 0.08 ppm which belongs to sample S18 to 2.96 ± 0.10 ppm which belong to sample S13 with a mean value of 1.37 ± 0.11 ppm. Furthermore, the uranium content in soil samples at the depth 40 cm varied from 0.30 ± 0.05 ppm which belongs to sample S18 to 2.89 ± 0.13 ppm which belongs to sample S13, with a mean value of uranium content is 1.15 ± 0.10 ppm. Uranium concentrations in samples vary with the depth of soil, where the mean value of uranium concentrations at a depth 0 cm is 2.12 ppm this value is higher than those of other depths. From these results the increasing factor was observed between the mean value of uranium content at depth (0 cm) with those of the other depths (10, 20, 30, and 40) cm is 115%, 130%, 150% and 189%, respectively. The results obtained show that the content of uranium in soil decreases with increased of soil depth. The reason behind such results can be attributed to the erosion factors and washing of surface layers of soil. The high level of radioactivity exists at the soil surface where the winds and rains can be removed 90% from radioactive material during the first months of soil pollution [16]. As well as the mineral composition of Iraqi soil and its containment of high proportion of calcium carbonate, iron oxides and aluminum are one of the factors leading to the retention of the radioactive materials and prevention its motion, the interaction of these materials with the solid part of the soil reflects the soil's ability to the retention of the radioactive materials and prevention its motion.

Table 2. Uranium concentrations in soil samples as a function of the depth of soil

| Depth (cm) | No. of sample | Min ± Std.Dev. | Max ± Std.Dev. | Mean ± Std. Error |
|-----------|---------------|----------------|----------------|-------------------|
| 0         | 20            | 0.71 ± 0.16    | 3.66 ± 0.13    | 2.12 ± 0.12       |
| 10        | 20            | 0.66 ± 0.10    | 3.38 ± 0.11    | 1.84 ± 0.15       |
| 20        | 20            | 0.41 ± 0.05    | 3.31 ± 0.11    | 1.64 ± 0.12       |
| 30        | 20            | 0.37 ± 0.08    | 2.96 ± 0.10    | 1.37 ± 0.11       |
| 40        | 20            | 0.30 ± 0.05    | 2.89 ± 0.13    | 1.15 ± 0.10       |

Figure 2 illustrates the total average value of uranium content in the soil samples of Al-Diwaniyah governorate as a function of location. This figure shows that the highest value of uranium concentrations in soil samples is 3.24 ppm which is found in Al-Hamad village this value is higher than the safety level of uranium concentration 2.8 ppm. This result can be attributed to this area was exposed to a high level of uranium weapons during the Gulf wars.

![Figure 2. Average of uranium concentration in the soil samples as a function of location](image-url)
Table 3 explains the concentrations of uranium in soil samples as a function of the region nature which included residential, agricultural and industrial areas. From this table the mean value of uranium content in soil samples collected from industrial areas is $3.07 \pm 0.12$ ppm; this mean value is higher than those of the agricultural and residential areas. The cause behind such results is due the human activities and the exposure of some industrial areas to uranium contaminants during the Gulf wars. The use of fertilizers in agricultural fields may be the cause of the presence of uranium concentrations in soil samples of the agricultural areas, the degree of uranium presence in soil samples is ranked as follows: industrial > agricultural > residential.

| Area classification | No. of samples | Mean ± Std. Error |
|---------------------|----------------|-------------------|
| Industrial          | 6              | 3.07 ± 0.12       |
| Agricultural        | 5              | 1.87 ± 0.11       |
| Residential         | 9              | 1.63 ± 0.12       |

The results of the present investigation were compared with those by the other researchers in locations elsewhere and are summarized in Table 4. As the present work was the first study ever carried out involving uranium content in soil samples of different areas of Al-Diwaniyah governorate southern Iraq, the results obtained are now serving as the reference data for future studies.

| No | Locations     | Mean   | Range      | References |
|----|---------------|--------|------------|------------|
| 1  | Mexico        | ......  | 2.6 – 13.7 | [9]        |
| 2  | India         | 4.62   | 1.47 – 10.66 | [17]       |
| 3  | Turkey        | ......  | 1.01 – 11.7 | [18]       |
| 4  | Brazil        | 3.21   | ......      | [19]       |
| 5  | Baghdad, Iraq | 1.05   | 0.40 – 2.53 | [20]       |
| 6  | Thi-Qar, Iraq | 2.077  | 0.77 – 2.89 | [10]       |
| 7  | Al-Diwaniyah, Iraq | 2.12 | 0.71 – 3.66 | Present work |

Conclusion
The uranium concentrations in soil samples have been determined by using fission track analysis technique FTA. Results of this work showed a decrease of uranium concentration with increased depth of soil. The recorded values were compared with the published data and were found to be within the acceptable limits.

Acknowledgments
Support from Department of Physics, College of Education, University of Al-Qadisiyah, Al-Diwaniyah, Iraq is gratefully acknowledged.

References:
[1] Al-Hamzawi A A, Jaafar M S and Tawfiq N F 2015 Concentration of uranium in human cancerous tissues of Southern Iraqi patients using fission track analysis Journal of radioanalytical and nuclear chemistry.303(3) 1703-1709.
[2] Al-Hamzawi A A, Jaafar M S and Tawfiq N F 2014 Uranium concentration in blood samples of Southern Iraqi leukemia patients using CR-39 track detector Journal of radioanalytical and nuclear chemistry.299(3) 1267-1272.
[3] Zou W, Bai H, Zhao L, Li K and Han R 2011 Characterization and properties of zeolite as adsorbent for removal of uranium (VI) from solution in fixed bed column Journal of Radioanalytical and Nuclear Chemistry. 288(3) 779-788.

[4] Banks D, Røyset O, Strand T and Skarphagen H 1995 Radioelement (U, Th, Rn) concentrations in Norwegian bedrock ground waters Environmental Geology. 25(3) 165-180.

[5] Bersina I G, Brandt R, Vater P, Hinke K and Schütze M 1995 Fission track autoradiography as a means to investigate plants for their contamination with natural and technogenic uranium Radiation measurements. 24(3) 277-282.

[6] Todorov P T and Ilieva E N 2005 Contamination with uranium from natural and anthropological sources Romanian Journal of Physics. 50(9-10) 25-30.

[7] AL-Hamzawi A A, Jaafar M S, Tawfiq, N F and Salih N F 2013 Uranium concentration in human blood using fission track etch technique Journal of Natural Sciences Research. (13)176-181.

[8] Khan H A and Qureshi A A 1994 Solid state nuclear track detection: a useful geological/geophysical tool Nuclear Geophysics. 8 (1) 1-37.

[9] Gamboa I, Espinosa G, Moreno A, Golorrri J J and Castillo F 1984 Uranium determination in mineral rocks by SSNTD Nuclear tracks. 8 (1-4) 443-445.

[10] Mansour H L, Tawfiq N F and Kari M S 2015 Measurement of uranium concentrations in soil samples for selected regions in Thi-Qar governorate by using (CR-39) nuclear track detector Engineering and Technology Journal. 33(6 Part (B) Scientific), 1127-1133.

[11] Danesi P R, Bleise A, Burkart W, Cabianca T, Campbell M J, Makarewicz M, Moreno J, Tuniz C and Hotchiks M 2003 Isotopic composition and origin of uranium and plutonium in selected soil samples collected in Kosovo Journal of environmental radioactivity. 64(2-3) 121-131.

[12] Oufni L 2003 Determination of the radon diffusion coefficient and radon exhalation rate in Moroccan quaternary samples using the SSNTD technique Journal of radioanalytical and nuclear chemistry. 256 (3) 581–586.

[13] Al-Hamzawi A A 2017 Natural Radioactivity Measurements in Vegetables at Al-Diwaniyah Governorate, Iraq and Evaluation of Radiological hazard Al-Nahrain Journal of Science. 20(4) 51-55.

[14] Al-Hamzawi A A, Jaafar M S and Tawfiq N F 2014 The measurements of uranium concentration in human blood in selected regions in Iraq Using CR-39 track detector Advanced Materials Research. (925) 679-683. Trans Tech Publications.

[15] Bem H and Bou-Rabee F 2004 Environmental and health consequences of depleted uranium use in the 1991 Gulf War Environment international. 30 (1) 123-134.

[16] Barišić D, Vertačnik A and Lulić S (1999) Caesium contamination and vertical distribution in undisturbed soils in Croatia. Journal of environmental radioactivity, 46(3), 361-374.

[17] Kakati R K, Kakati L and Ramachandran T V 2013 Measurement of uranium, radium and radon exhalation rate of soil samples from Karbi Anglong district of Assam, India using EDXRF and Can technique method APCBEE procedia. (5) 186-191.

[18] Baykara O and Dogru M 2006 Measurements of radon and uranium concentration in water and soil samples from East Anatolian Active Fault Systems (Turkey) Radiation Measurements. 41(3), 362-367.

[19] Geraldo L P, Serafim R A, Corrêa B A, Yamazaki I M and Primi M C 2010 Uranium content and dose assessment for sediment and soil samples from the estuarine system of Santos and São Vicente, SP, Brazil Radiation protection dosimetry. 140(1), 96-100.

[20] Kadhim N H and Kadhim S S 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. 8(1), 17-20.