# Determining the Concentrations of Uranium in Selected Soils in Mosul City with Nuclear Track Detectors (CR-39)

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In the present study, the values of uranium in 25 soil samples taken from particular sites around the northern Iraqi city of Mosul were determined using the CR-39 nuclear track detector, which is the center of the Nineveh governorate, where the samples were irradiated with thermal neutrons to obtain fission fragments (n, f), After chemical etching, an optical microscope was used to calculate the number of fission fragments in the alpha particle's pathway. The findings indicated that the Ibn Sina Hospital site had the highest uranium concentration among the studied sites, at 13.8144 ppm, and the Toaleb area has the lowest result, by 2.0146 ppm; it should be noted that 11.7 ppm is the recommended value by UNSCEAR (1993).

**Keywords:** Mosul city, uranium, soil samples, CR-39 detector.

## 1. Introduction

Uranium is one of the natural components of the soil and its concentration ranges between (1-120 ppm), it is a toxic silvery-white heavy metal with poor electrical conductivity, which emits alpha particles (α) with a decay constant of $1.5*10^{-10}yr^{-1}$ with a radioactivity of 12.4*103Bq/g, natural uranium consists of three isotopes, which are $^{238}U$ 99.274%, $^{235}U$ 0.714% and $^{234}U$ 0.0055% , and it is believed that a large part of the heat of the earth's interior is caused by radiation from uranium [1].

Uranium is present in most types of rocks to varying degrees, usually in small concentrations, as it is widely distributed in the earth's crust, soil and rocks at a concentration ranging from (2-4 ppm) [2]. Solid-state nuclear track detectors were utilized to count the tracks of fission fragments in order to determine the amount of uranium in the soil, where this technique of detecting and measuring the concentration of uranium is considered one of the best methods, due to its simplicity and low cost and does not require complex electrical and electronic devices, in addition to its sensitivity and high efficiency in identifying even in very low concentrations, the alpha particle producing components [3,4].

The soil is the uppermost layer of the earth's crust that has been formed by weathering and human activity on the rocks of the crust. These rocks have been deformed by a variety of intricate physical and chemical processes, including changes in atmospheric conditions and water movement [4]. The fragile layer of soil that covers the rocks of the earth's crust ranges in thickness from a few centimeters to several meters, and it is a complex mixture of minerals. The soil is the most significant component of the environment that gives man a food crop, organic materials water, air, and chemical substances that the plant can rely on to grow and discover the ingredients of life. However, because this is a dynamic medium, pollution from it can cause long-term environmental problems that contaminate food, water, and air. [5].

Soil pollution is generally achieved when one of its elements is added or lost, which causes an imbalance that changes its natural properties (chemical or biological), and directly or indirectly affects humans, plants and animals. Understanding the nature of these materials, their risks, and appropriate handling techniques became essential as a result of the significant advancements in science and technology that led to the production of radioactive materials and their widespread applications, as the contamination of soil with uranium leads to a direct threat to human health, so a number of studies were conducted to find uranium concentrations in various vital aspects for human[6,7,8].

The aim of the study is to use the solid-state nuclear track detectors technology CR-39 to determine the content of uranium in the soil of those sites using three samples from each site and a depth of 10 cm. The study is being carried out in Mosul, the center of the Ninevah governorate in northern Iraq.

## 2. Material And Methods

Soil sample collection:

The soil samples utilized in this study were collected in September 2023 from the Shifa Medical Area (Mosul medical city) and the Al-Medan neighborhood near the Iron Bridge, as well as from the Mosul city center and the west bank of the Tigris River (right side). Furthermore, a total of 25 samples were collected at a depth of 10 cm below the soil surface from the eastern (left) side of the city of Mosul. To calculate the uranium content of the samples, certain models was created. After being brought, they were dried in an oven at a temperature of 70 $^{O}$C for a few hours, and they were ground and sifted with a sieve size of 75 µm, then weighing 0.5 g of each soil sample and pressed in the form of a pellets with a thickness of 2 mm and a diameter of 1 cm by means of a hydraulic press.

Irradiation of samples:

The samples were irradiated with the neutrons Source (Am-Be) at the College of Education – Ibn Al-Haytham-University of Baghdad, where the soil pellets were placed directly with the nuclear track detector (CR-39), with an empty detector without samples, for the purpose of irradiating them with thermal neutrons by the Neutron Source (Am-Be) surrounded by paraffin wax and at a distance of 5 cm for 7 days, at which time they would have been exposed to a neutron flux of ($5*10^3$ n $cm^{-2}$ $s^{-1}$).

Paraffin wax is usually used to moderating the fast neutrons and convert them into thermal neutrons (0.025 eV) as shown in figure (1)

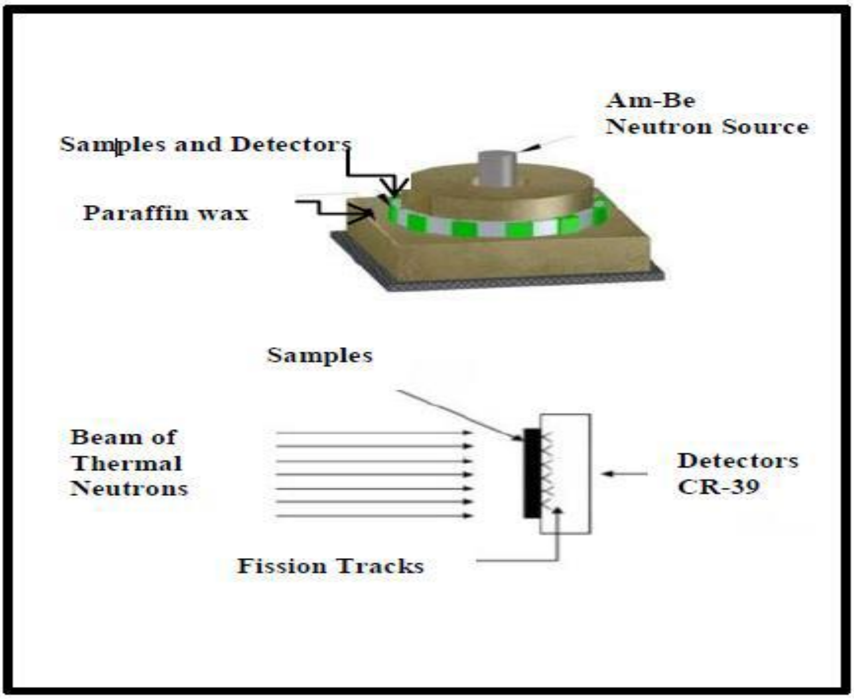


Figure 1. Neutron source irradiation of samples and detectors [9]

Chemical etching and microscopy scanning:

In most situations, showing the tracks entails executing chemical etching for specific durations of time with the goal of removing reagent particles that have been damaged by charged particles. After the neutron irradiation period, the detectors were chemically etched by immersing them in an aqueous solution of sodium hydroxide with a normality of 6.25 N for 6 hours at 60 °C, which is the standard time for etching the CR-39 detector.

The detector was then washed with distilled water and dried, then microscopic examination was done with an optical microscope to find the number of fission fragment track recorded in the CR-39 detector at 400x power.

Calculation of uranium concentration:

The density of fission tracks (ρ) was determined using the following equation [4]:

$$\text{Track Density } (\rho_x) = \frac{\text{Av.of total track(Nave)}}{\text{Area of field view(A)}} \quad \text{---------(1)}$$

Where: ρx: track density (tr/mm$^2$)., Nave: the rate of total effects within the space (A). ,A: the area is in (mm$^2$).

To determine uranium concentrations generally rely on the presence of standard samples for comparison between them, Figure (2) represents the relationship between track density and uranium concentrations for the detector's sample standards [11].

The uranium concentrations of the soil samples in this study were determined by comparing the results between the track densities obtained with the standard track density (after subtracting the tracks recorded in the blank detector), and by the following equation [10]:

$$\frac{\text{Cx samplex}}{\text{Cs standard}} = \frac{\rho\text{x sample}}{\rho\text{s standard}} \text{ ------------------- } (2)$$

Equation (2) can be written in the following formula:

$$C_x = \rho_\times (C_s/\rho_s) \text{ ------------------------- } (3)$$

Where is that:

$\rho_\times$ and $\rho_s$: The track density of fission fragments from unknown and standard samples, respectively in units ($Tr/mm^2$).

$C_x$ and $C_s$: the level of uranium concentration in the unknown and standard samples, respectively, in units (ppm).

The slope of the linear relationship between track density and the uranium level of standard soil samples shown in Equation (3) represents the value ρs/Cs according to which the uranium concentration was measured in unknown soil samples, where the final equation can be expressed:

$$C_x = \frac{\rho x}{\text{slope}} \text{ ---------------------------- } (4)$$

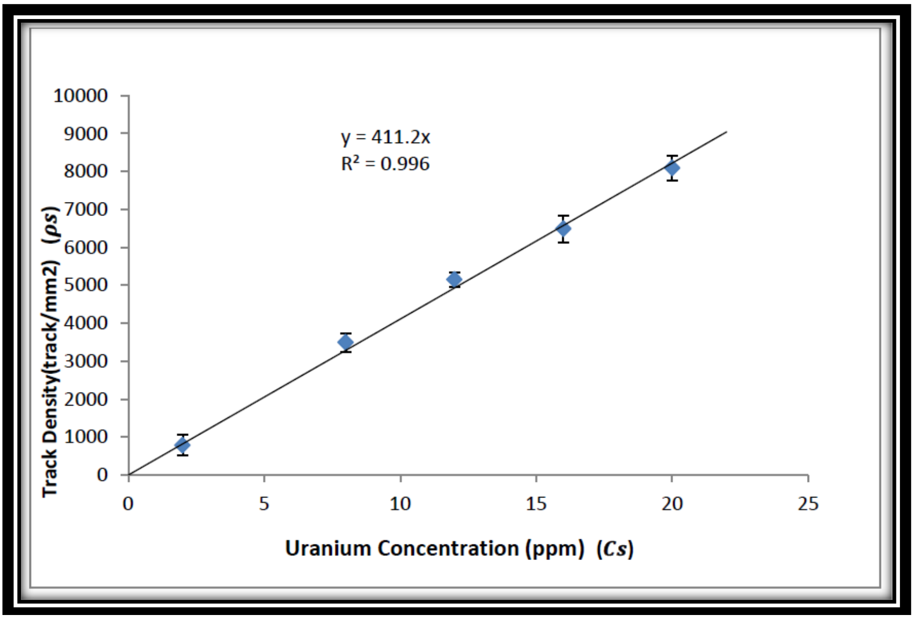


Figure 2 : calibration curve between track density and uranium concentration for standard samples of the CR-39 detector.[11].

The uranium concentrations in soil samples from the studied sites are shown in Table (1) and

Figure (3).

Table 1: Uranium concentrations found in soil samples collected from different locations in Mosul.

| Sample No | Sample Code | Sites | Tracks density (tracks/mm$^2$) | Uranium Concentrations (ppm) |
|---|---|---|---|---|
| 1 | M1D | Al-Medan 1 | 1360.946 | 3.3097 |
| 2 | M2D | Al-Medan 2 | 3491.124 | 8.4901 |
| 3 | M3D | Al-Medan 3 | 1065.088 | 2.5902 |
| 4 | M4D | Al-Medan 4 | 946.745 | 2.3024 |
| 5 | Q5D | Qulayyat 1 | 2011.834 | 4.8926 |
| 6 | Q6D | Qulayyat 2 | 1420.118 | 3.4536 |
| 7 | SH7D | Al-Shahwan | 1195.266 | 2.9068 |
| 8 | SHB8D | Sheikh Al-Shatt 1 | 1420.118 | 3.4536 |
| 9 | SHB9D | Sheikh Al-Shatt 2 | 1656.800 | 4.0292 |
| 10 | N.G.SH10D | The Prophet Gargis | 970.414 | 2.3600 |
| 11 | T.11D | Toaleb | 828.402 | 2.0146 |
| 12 | K.S.12D | Qara Saray | 1065.088 | 2.5902 |
| 13 | N.H.13D | Nineveh health directorate | 2248.521 | 5.4682 |
| 14 | B.14D | Bashtabya Castle | 3372.780 | 8.2023 |
| 15 | M.M15D | Mosul Medical City / Emergency building | 4142.011 | 10.0730 |
| 16 | M.M16D | Mosul Medical City / Al-Batool hospital | 3195.266 | 7.7706 |
| 17 | M.M17D | Mosul Medical City / blood bank | 4378.698 | 10.6486 |
| 18 | M.M18D | Mosul Medical City / Consulting Center | 3550.295 | 8.6340 |
| 19 | M.M19D | Mosul Medical City / Ibn-Senna hospital | 5680.473 | 13.8144 |
| 20 | M.M20D | Mosul Medical City / dialysis center | 5207.100 | 12.6632 |
| 21 | M.M21 | Mosul Medical City / Atomic medicine | 4437.869 | 10.7925 |
| 22 | L.S1D | Rashidiyya | 2426.030 | 5.8999 |

| | | | | |
|---|---|---|---|---|
| 23 | L.S2D | Sumer | 2011.834 | 4.8926 |
| 24 | L.S3D | AL- Gufran | 4556.213 | 11.0803 |
| 25 | L.S4D | Nabi Yunus | 3017.750 | 7.3389 |
| Average | | | 2626.271 | 6.1412 |

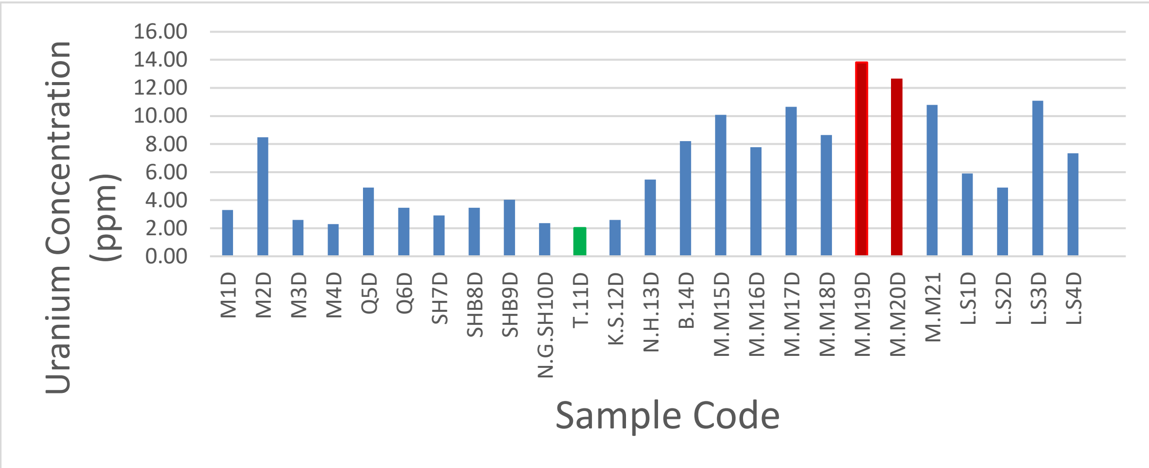


Figure 3: The relationship between geographic location and uranium concentration of soil samples collected from different locations using CR-39.

Table (1) and Figure (3) show that the uranium concentrations in the samples under study varied somewhat, It shows that the Shifa Medical The site (Mosul Medical City), where the Ibn-Senna hospital is located, has the greatest percentage of uranium in the soil (13.81ppm), a value considered high, exceeding the value of the recommended limit for the concentration of uranium in the soil specified by (UNSCEAR, 1993), which set the maximum concentration of uranium is (11.7 ppm) [12], the reason may be a consequence of the exposure of the area to aerial bombing and military operations that took place during the period 2014-2017, as well as the presence of radioactive isotopes used for medical purposes in cancer oncology centers and the atomic Medicine Center. While the lowest concentration of uranium for the studied region was in the Al-Toaleb area, where the concentration of uranium reached (2.0146 ppm), although these areas were bombarded and destroyed during that period.

## 3. Conclusions

The results obtained showed that from measuring the concentration of uranium in soil samples in the areas under study:

- The highest value of uranium measured was 13.81 ppm, indicating that there are places where the concentration is higher than the allowable limit of 11.7 ppm.
- The uranium levels at the other study sites tend to be relatively high even if they are within the allowable limit.

- In all of the study cities, the average uranium content was 6.1412 ppm.

## 4. Recommendations

- Performing additional research to detect uranium in other Mosul places particularly those hit by bombing, and determine the uranium concentrations in those places.
- The pollution should be addressed by the appropriate authorities, particularly since the Medical City, which accommodates patients, staff, and visitors, has the greatest uranium content.

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