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# Estimation of Uranium Concentrations in Urine Samples for Several Different Ages of Patients Using the Nuclear Track Detector CR-39: A Case Study of Nineveh Governorate

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## Abstract

This article aims to measure uranium concentrations in human urine samples from various patients using a nuclear trace detector CR-39. The study was conducted in Nineveh Governorate. The samples were collected by 27 urine samples taken from patients who attended health centers in Nineveh Governorate. The differences in patients' age were considered in the calculations. The findings showed that all urine samples consisted of uranium contamination. Furthermore, as the patient's age increases, the percentage of uranium concentration in his urine increases due to the inability of the kidneys to get rid of uranium deposits.

## Keywords

Uranium, Urine, CR-39, Patients.

Uranium is one of the most important primitive radionuclides in the Earth's crust. It was discovered by the scholar Klaproth in 1789. It is a silver, shiny, and dense radioactive element with radioactivity. It is found throughout the natural environment, such as rocks, soil, water, air, plants, animals, and the human body [1].

Uranium is found widely in nature as a wide variety of solid, liquid and gaseous compounds, easily combining with other elements from uranium oxides [2]. These compounds differ greatly in their chemical properties and their toxic effects. The solubility of uranium varies according to the special compounds and solvents. Furthermore, solubility determines: 1) how quickly the body absorbs it from the lungs; and 2) how efficiently the body absorbs it from the intestines [3].

Uranium can be found in nature in three isotopes: $^{234}_{92}U$, $^{235}_{92}U$, and $^{238}_{92}U$. It forms Uranium-238, about (99.27%) of all natural uranium. It is believed heat is caused by radiation emanating from uranium [4].

In the literature, the calculation of radioactive substances concentrations has attracted many scholars. For example, uranium in blood, urine in the rest of the human body, air, soil, and building materials [5]. To accomplish this objective, different techniques were used, such as gamma-ray spectroscopy, X-ray fluorescence, and neutron activation analysis. Additionally, the technique of counting the effects of fission fragments using a nuclear trace detector CR-39 [6].

It is well-known that nuclear trace detector CR-39 is more preferred because it is simple and does not require complex and inexpensive devices. These devices are solid materials that are electrically insulated. They can store the effect of ionizing radiation in the form of damage or damage to their internal structure. It can be kept for a long time, as a light microscope can see the damaged areas after treating it with some abrasive chemical solution [7]. This nuclear detector CR-39 is considered one of the best detectors for recording traces of fission fragments of alpha particles, protons and neutrons [8].

Furthermore, it is not affected by weather factors, such as temperature and humidity, when stored for long times under natural conditions. It does not dissolve in abrasive solutions due to this detector's characteristics and advantages. It has been used in many applications and many fields, including its use to measure uranium and radon concentrations in different places, and the alpha particles emitted from uranium do not penetrate the outer layers of the skin. However, they affect the internal cells of the body when uranium is swallowed or inhaled, where ingested uranium is stored in the bones, liver, and kidneys. The kidney is the organ most sensitive to uranium toxicity because uranium slowly destroys the kidneys. Also, uranium works on bone necrosis and delayed growth when exposure to uranium is frequent, and here should be noted that uranium may turn the human body into another radioactive material, radium, which may cause cancer [9].

## Experimental Procedure

This article aims to measure uranium concentrations in urine samples of patients who attended a health center in Mosul city (in the north of Iraq). Samples were collected from patients in August 2022 at the primary health care center in the Al-Nour neighborhood in Nineveh Governorate. To calculate the concentrations of uranium, nuclear trace detectors CR-39 are equipped with an appropriate area $(1.5 \times 1.5)\ cm^2$. The materials and equipment are installed according to the size of the urine sample. Next, the samples were classified in a table containing the following:

1. Patient age.
2. The intensity of the effects of uranium fission fragments.
3. The concentration of uranium in each sample, where the uranium concentrations in urine samples were determined using the technique of counting traces of fission fragments with a nuclear trace detector CR-39

Here, a drop of urine of known volume $(100\mu l)$ is dripped onto a piece of CR-39 squared with a known surface area. It is conducted in a dust-free atmosphere at normal room temperature (see Figure 1).

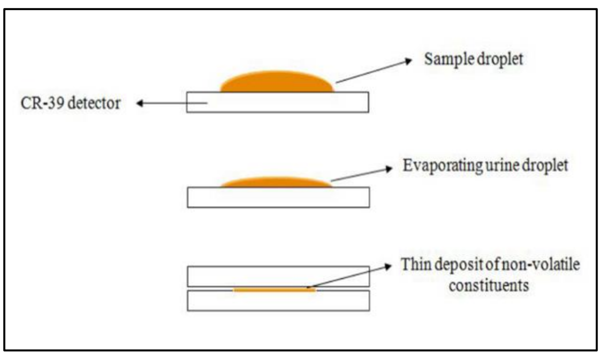


**Figure 1:** Evaporation of the sample droplet and the formation of a thin deposit [10].

Next, the detector piece is covered with another detector piece. Additionally, the urine samples are exposed to a beam of thermal neutrons for seven days (flux of $5 \times 10^3\ n\ cm^{-2} s^{-1}$), and with a total fluence of $(3.02 \times 10^9 n\ cm^{-2}\ s^{-1} atotal)$. As shown in Figure 2, Am-Be is used as a neutron source.

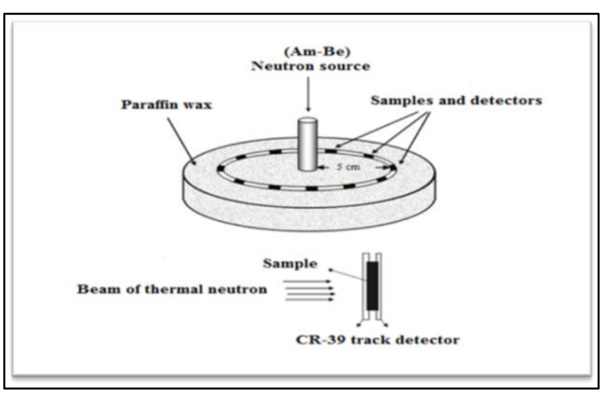


**Figure 2:** The irradiation of the detectors and samples to the neutron source [9].

The urinal acetate $(cH_3\ coo)_2\ Uo_2$ is used to prepare a standard uranium solution. Then, according to the interaction between (n and f), we used the following equation to determine the fission that occurred on the detector [11]:

$$^{235}_{92}U + ^{1}_{0}n_{thermal} \rightarrow ^{236}_{92}U^{*} \rightarrow ^{141}_{56}Br + ^{92}_{36}Kr +$$

After exposure of urine samples to irradiation, the nuclear detector (CR-39) is drilled in 6.25 N of NaoH at 60C$^0$ for about six hours. As formulated in Equation 2, the solution is prepared using a volumetric technique [12]:

$$W = W_{eq} . N . V \qquad (2)$$

where $W$ defines the weight of NaoH, and $W_{eq}$ denotes the equivalent weight of NaoH. Additionally, $N$ is the normality (equals 6.25), and $V$ defines the volume of distilled water (250 ml)

Then, microscopic observation of the samples is performed. It represents the last step in the process of detecting traces, as it was viewed using a light microscope and with magnification (400X). After that, from the following formula, we read the traces per unit area to get the density of the traces [10]:

$$Track\ Density\ (p) = \frac{Average\ number\ of\ total\ track}{Area\ of\ field\ view} \qquad (3)$$

We calculated the uranium concentration in urine samples by comparing the traces density that we recorded in the detector and the density of standard solutions, as formulated in Equation (4) [13]:

$$C_x = \left(P_x/P_s\right) . C_s \qquad (4)$$

$C_x$ and $C_s$ denote uranium concentrations for the unknown samples and standard samples, respectively, in a unit (ppb). $P_x$ and $P_s$ are the induced fission track density for unknown and standard samples, respectively, in a unit (tracks /mm$^2$).

As illustrated in Figure 3, by drawing the graphic relationship between uranium concentrations and the density of traces of standard samples, one can find the uranium concentrations in the unknown samples using Equation (5).

$$C_x = \frac{P_x}{slope} \qquad (5)$$

where $C_x$ denotes the uranium concentration measured in units $(\mu g/l)$.

## Results and Discussion

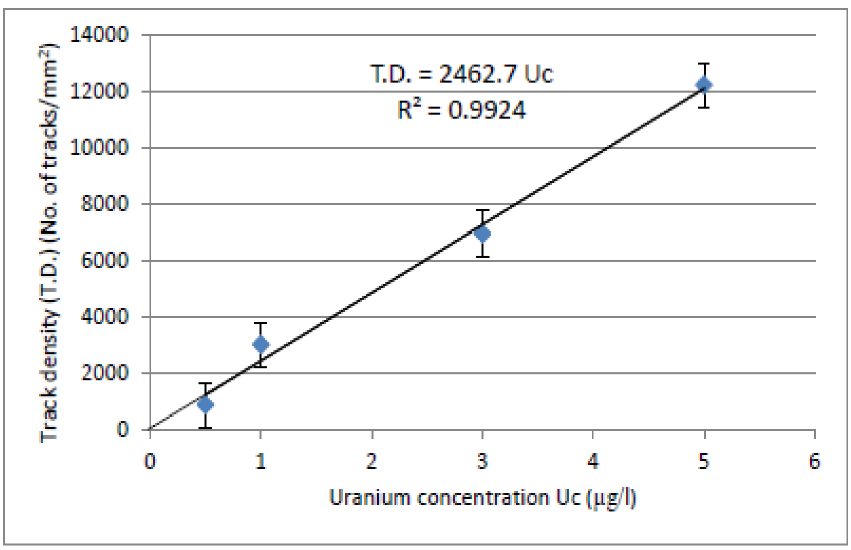


**Figure 3:** The relation of uranium concentration and track density in the standard samples [14].

Accordingly, we calculated uranium concentrations in 27 urine samples in the assigned Nineveh Governorate. We performed that using the technique of counting traces of fission fragments in the detector CR-39 resulting from the bombardment of uranium nuclei $^{235}_{92}U$ with thermal neutrons. Then, as shown in Figure 3, uranium is found by approved calculations compared to standard samples.

Table 1 lists the uranium concentrations of the selected patients. It shows that the highest concentration of uranium was (1.68 $\mu g/l$) for a patient from Mosul center in Nineveh Governorate. The increase in the concentration in his urine is because he is a patient with nephritis who smokes and is 69 years old. Consequently, an increase occurs in the uranium concentration in the patient's urine, as the concentration varies from one patient to another according to age, gender, and the number of years of the disease.

Here, it is important to mention that the geographical nature of the location significantly impacts reducing/increasing the uranium concentration. Specifically, if the area where warfare took place or where there is a percentage of contamination with radioactive materials and enriched uranium from other areas has been used. This concentration is considered high compared to the internationally permitted concentration [15]. Furthermore, the lowest uranium concentration was ($0.84\,\mu g/l$) for a woman from the center of Mosul (Nineveh Governorate, north of Iraq). The reason for this low concentration compared to the rest of the patients is that she is young, at about (31) years old. Furthermore, she has recently been infected with cystitis and does not smoke. Moreover, the nature of the area where the infected person lives, as she was not exposed to any industrial radioactivity.

**Table 1:** Uranium concentrations for patients in 27 urine samples in Nineveh Governorate.

| No. | Age (year) | Gender | Smoking | Track density (Track/mm$^2$) | Uranium Concentration ($\mu g/l$) |
|---|---|---|---|---|---|
| 1. | 17 | F | Non | 2189.34 | 0.88 |
| 2. | 57 | F | S | 2662.72 | 1.08 |
| 3. | 30 | F | Non | 2366.86 | 0.96 |
| 4. | 22 | F | Non | 248.52 | 0.91 |
| 5. | 52 | F | Non | 2603.55 | 1.05 |
| 6. | 66 | F | S | 3076.92 | 1.24 |
| 7. | 42 | M | S | 2544.37 | 1.03 |
| 8. | 31 | F | Non | 2071.00 | 0.84 |
| 9. | 39 | F | Non | 2189.34 | 0.88 |
| 10. | 50 | F | Non | 3017.75 | 1.22 |
| 11. | 70 | F | Non | 4023.66 | 1.63 |
| 12. | 30 | F | Non | 2662.72 | 1.08 |
| 13. | 72 | M | Non | 3786.98 | 1.53 |
| 14. | 69 | F | Non | 3846.15 | 1.56 |
| 15. | 29 | M | Non | 2603.55 | 1.05 |
| 16. | 37 | F | Non | 2426.05 | 0.98 |
| 17. | 30 | F | Non | 2248.52 | 0.91 |
| 18. | 55 | F | S | 3372.78 | 1.36 |
| 19. | 50 | F | Non | 2958.57 | 1.20 |
| 20. | 35 | F | Non | 2307.69 | 0.93 |
| 21. | 35 | M | Non | 2662.72 | 1.08 |
| 22. | 32 | F | Non | 2130.17 | 0.86 |
| 23. | 31 | F | S | 2248.52 | 0.91 |
| 24. | 53 | F | Non | 2840.23 | 1.15 |
| 25. | 69 | M | S | 4142.01 | 1.68 |
| 26. | 53 | M | S | 3136.09 | 1.27 |
| 27. | 44 | M | Non | 3017.75 | 1.22 |

S = smoker, and Non = nonsmoker. F = Femal, and M = Male

## Conclusions

In this article, we measure uranium concentrations in human urine samples from various patients using a nuclear trace detector CR-39. Solid-State nuclear trace detectors (SSNTD$_s$) were used because they are easy to use, inexpensive, and do not require complex electronic equipment. They are modern and simple technologies that give high-accuracy results. The study was conducted in Nineveh Governorate. The samples were collected by 27 urine samples taken from patients who attended health centers in Nineveh Governorate. From the results, we conclude the following:

1. We found that the highest concentrations of uranium were ($1.68\,\mu gm/l$) to a male patient (69 years old). The lowest percentage of uranium concentration was ($0.84\,\mu gm/l$) to a female patient (31 years old. This means that the higher the patient's age, the higher the uranium concentration in his urine.
2. Concentrations of uranium in the urine in the light of the current research are higher than the permissible limit value of the ICRP organization of 0.5μg/l .
3. The increase in uranium concentration with age is caused by increased dietary intake and the accumulation of uranium in the body.

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