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Measurement of uranium concentration in the water samples collected from the areas surrounding in Al-Tuwaitha nuclear site using the CR-39 detector

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Abstract. In this research, the uranium concentration in (16) water samples collected from some agricultural areas surrounded with AlTuwaitha nuclear site in Baghdad-Iraq was measured by using a CR-39 detector. The concentration of uranium in this study was from $(0.6 \pm 0.33\text{mg/l})$ to $(2.51 \pm 0.49\text{ mg/l})$, and the weighted average for the concentrations $(1.262 \pm 0.402\text{ mg/l})$. The results showed it is a concentration of uranium level in water samples studied is higher than the allowed limit recommended by WHO and ICRP.

1. Introduction

The human is exposed to radioactivity with varying ways, including is ingesting and inhaling radionuclides existing in food, water, and air. It is known that uranium is one of the most important radioactive elements in nature, which is widespread in the crust of the earth [1].

Uranium is a chemical element within the chain of actinides of the periodic table, a silver-white metal. Uranium has many isotopes, the most important ^{238}U , ^{235}U , and ^{234}U [2].

Uranium concentration can be detected in water either in dissolved form or in particle form [3]. Uranium is classified as a radioactive contaminant, especially in drinking water. The Uranium, radium, and radon are considered to be the most important known radionuclides found in water[4].

The accumulation of uranium in the body of the organism leads to radiological and chemical effects. The main sites of the deposition of uranium in the body of the organism are bone, liver, and kidneys. The toxicity of uranium depends on several factors, including the path of exposure, particle solubility, time of contact, and the method of removal [4].

The concentrations of toxic radioactive elements, including uranium in drinking water, are always given great attention by various health organizations. The World Health Organization (WHO) previously recommended that the allowed limit for uranium in water is 0.015 mg/l, and after extensive studies of this organization, the allowed limit now recommended by the (WHO) in drinking water is 0.03 mg/l [5, 6].

Either the allowed limit level for uranium in the water recommended by ICRP is 0.019 mg/l [7]. While the Maximum allowed limit of uranium in water specified by India's Atomic Energy Regulatory Board (AERB) is 0.06 mg/L [8].



In this study, the CR-39 detector was used to measure uranium concentrations in samples of water collected from some agricultural areas of the surrounded with AlTuwaitha nuclear research center (AlTuwaitha nuclear site) in Baghdad, Iraq.

The CR-39 detector is one of the solid-state nuclear track detectors, it is solid and transparent plastic, its chemical formula is $C_{12}H_{18}O_7$ and has a density of (1.30 g / cm^3) . It is usually made of the polyallyl diglycol carbonate (PADC) resin. The detector is widely used in many fields of science, particularly in the measurements of nuclear physics, radiography of charged particles, radon dosimetry, and many radiological experiments. This detector is characterized by its high sensitivity, which makes it able to record the low energies of alpha particles[9, 10].

2. Methods and material

- 1) Five standard samples were prepared with different concentrations of water by using powdered uranium acetate, which chemical formula $UO_2(CH_3COO)_2 \cdot 2H_2O$ molecular weight of (424), which contains ^{238}U (56.13%). Where prepared concentrations (2,8,12,16 and 20) mg/l by using the following relationship [11]:-

$$\text{Concentration 1} \times \text{Volume 1} = \text{Concentration 2} \times \text{Volume 2}$$

- 2) The CR-39 detector was cut into small pieces with an area of (1 cm^2) per piece.
- 3) The samples of water were collected from the surround locations with the Tuwaitha nuclear site in Baghdad, as shown in **Table 1**. The samples were collected with volume (4) liter and added (0.004) liters of nitric acid for each sample for the purpose of avoiding hydrolysis. The water samples were cleaned and put in a beaker size (4) litter and put the beaker in an oven at (80°C) for (16 hours) in order to reduce water from (4 liters) to (1 liter) to concentrate radionuclides in water.

Table 1. The code of sample, and the location of the study samples (All the locations surround with Al-Tuwaitha nuclear site).

Sample code	Type of water	Location
W1	Well	Near rotated Salman
W2	Tap	Near stores
W3	Tap	The Municipal Council
W4	Well	Ibn Zahr hospital
W5	Well	Beginning Al-Tuwaitha nuclear site
W6	River	End Al-Tuwaitha nuclear site
W7	Well	Towers high-pressure
W8	Well	An agricultural area close to the high-pressure Towers
W9	River	Al Bustan near the end of the Al-Tuwaitha nuclear site
W10	River	Department liquefaction water
W11	Well	Jabir Ibn Abdullah Ansari neighborhood (farm A)
W11-1	Tap	Jabir Ibn Abdullah Ansari neighborhood (farm A)
W12	Tap	Jabir Ibn Abdullah Ansari neighborhood (farm B)
W13	Tap	Jabir Ibn Abdullah Ansari neighborhood (farm C)
W14	Well	Jabir Ibn Abdullah Ansari neighborhood (farm D)
W15	Tap	Ishtar region

- 4) The micro-pipette was used in the modeling process. Where the volume of $(0.05 \mu\text{l})$ was pulled and placed on the detector piece and the detector has been left until water drought.

- 5) After dryness of the water, another piece of the nuclear track detector was placed above it (sandwiches) and it was glued tightly with transparent adhesive tape to prepare it for the irradiation process.
- 6) The irradiation process was carried out by placing of the standard and unknown samples within a paraffin wax system, with distance (5 cm) away from the neutron source ($^{241}\text{Am} - ^9\text{Be}$) and as shown in 'Figure 1' with flux ($10^5 \text{ n. cm}^{-2} \text{ s.}^{-1}$) and the flocunce of thermal neutron ($6.048 \times 10^{10} \text{ n/cm}^2$) for (7 days), to obtain induced fission fragments according to the equation 1.

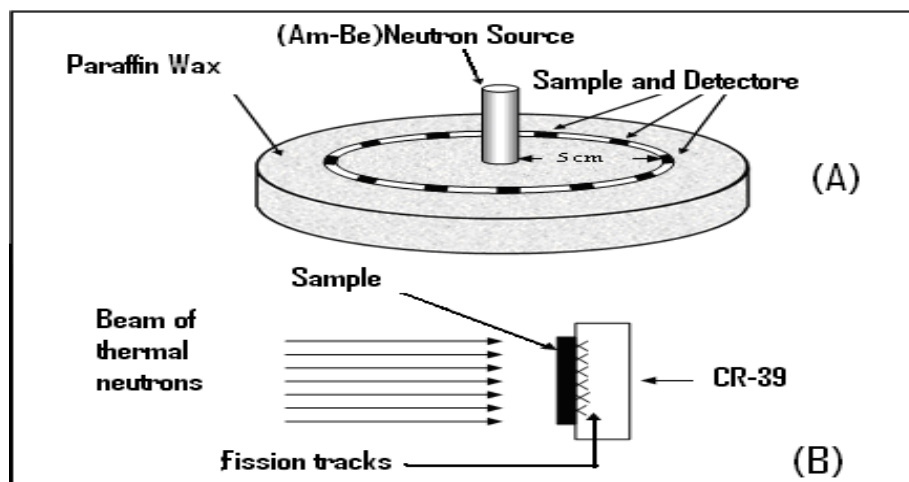
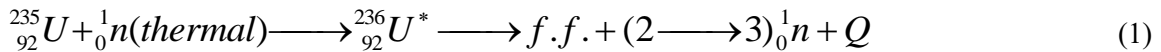


Figure 1. The irradiation of the samples and detectors

- 7) After that the each of samples put in the sodium hydroxide solution with normality (6.25N) and (60°C) temperature to accomplish the process of etching.
- 8) After etching chemical, begin the process of the track observation by optical microscope: (Novel) made in China: It is capable of giving magnifications by an objective (4x, 10x, 40x and 100x) and two eyepieces (10x) to measure the number of nuclear tracks. After counting the tracks of nuclear fission fragments and alpha particles on the surface of the detector, the track density calculated by the average of the total tracks divided by area of the field view. The tracks are shown in 'Figure 2'.

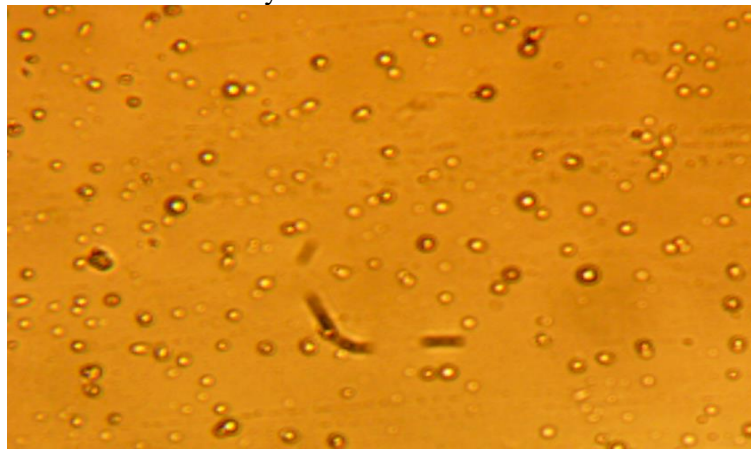


Figure 2. The tracks recorded on the CR-39 detector.

- 9) The uranium concentration in the water samples was measured by comparing tracks density registered on the detectors of the unknown sample with track density registered for the standard geological sample of water according to the relation [12]:-

$$C_X = C_S \left(\frac{\rho_x}{\rho_s} \right) \quad (2)$$

$$C_X = \frac{\rho_x}{\text{Slope}} \quad (3)$$

Where:

C_X : Concentration of uranium in an unknown sample (mg/l or ppm).

C_S : Concentration of uranium in the standard sample (mg/l or ppm).

ρ_x : Track density of unknown sample (tracks/mm²).

ρ_s : Track density of standard sample (tracks/mm²).

The 'Figure 3' shows a track density relation with a concentration of uranium in standard water samples.

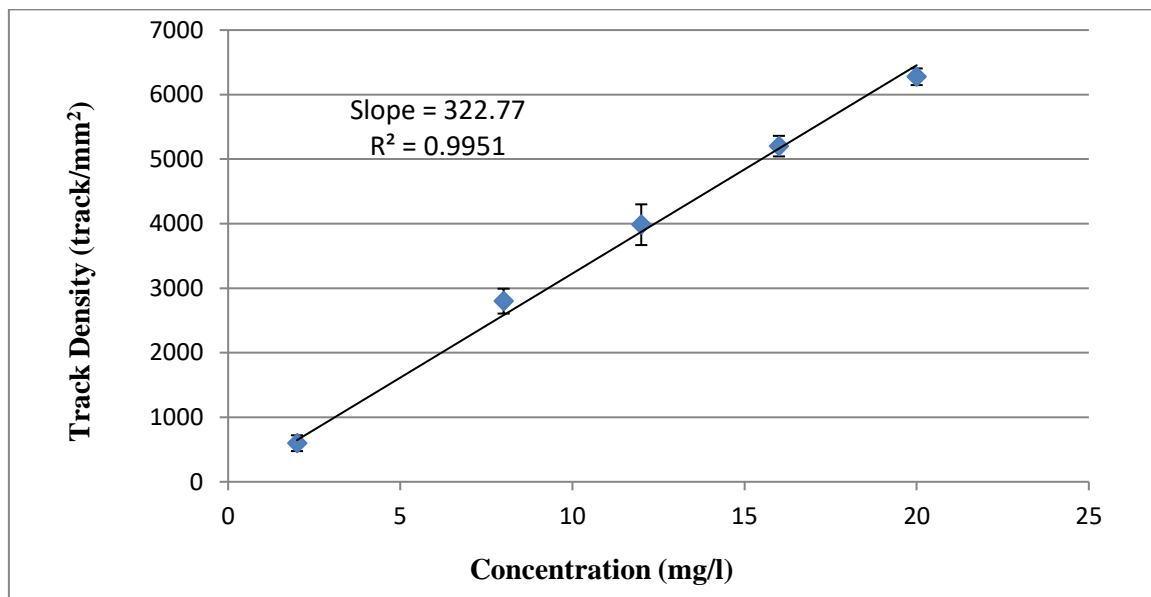


Figure 3. The concentration of uranium and track density in the standard water samples.

3. Result and discussion

In the present work, the samples of water were selected from agricultural regions which surround the Tuwaitha nuclear site to measure the level of contamination with uranium for these regions. The calculation of uranium concentration was achieved by using the technique of counting the tracks of nuclear fission fragments using the CR-39 detector. Table 2 shows the track density and concentration of uranium in water samples studied.

The monitor of the pollution level in those regions is necessary to estimate the danger arising from the radiation and quickly processed to ensure the safety of the population.

From Table 2, I find that the uranium concentrations in water samples ranged from $(0.6 \pm 0.33 \text{ mg/l})$ in the sample (W12), and $(2.51 \pm 0.49 \text{ mg/l})$ in the sample (W7), and the weighted average for the concentrations $(1.262 \pm 0.402 \text{ mg/l})$.

These results are higher than recommended allowed limit by WHO, which is equal to (0.03 mg/l)[6] and ICRP, which is equal to (0.019 mg/l)[7]. The 'Figure 4' shows a uranium concentration relationship with the code of the sample.

Table 2. Results a tracks density and concentration of uranium in the water samples.

Sample code	Tracks density (track/mm ²)	Uranium concentration (mg/l)
W1	258.92 ± 209.3	0.8 ± 0.64
W2	198.21 ± 183.35	0.61 ± 0.56
W3	498.21 ± 104.27	1.54 ± 0.32
W4	450 ± 147.44	1.39 ± 0.45
W5	307.14 ± 151.7	0.95 ± 0.47
W6	408.92 ± 242.43	1.26 ± 0.75
W7	812.5 ± 159.77	2.51 ± 0.49
W8	746.42 ± 150.3	2.31 ± 0.46
W9	491.07 ± 254.11	1.52 ± 0.78
W10	426.78 ± 247.78	1.32 ± 0.76
W11	553.57 ± 207.05	1.71 ± 0.64
W11-1	301.78 ± 105.29	0.93 ± 0.32
W12	194.64 ± 109.25	0.60 ± 0.33
W13	216.07 ± 161.14	0.66 ± 0.49
W14	598.21 ± 328.65	1.85 ± 1.01
W15	457.14 ± 277.94	1.41 ± 0.86
Weighted average		1.262 ± 0.402

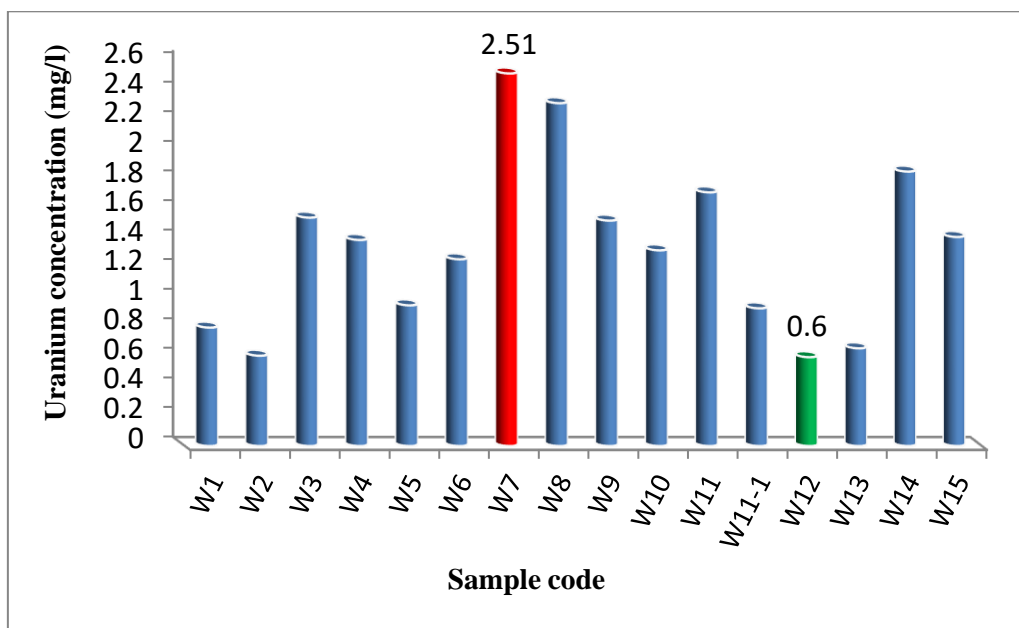


Figure 4. The maximum and minimum for uranium concentration in the water samples.

4. Conclusion

- 1) A small variation in the concentrations of uranium was observed in the water samples analyzed.
- 2) In this regions, the concentration of uranium in (16) water samples were found to variation between (0.6 - 2.51) mg/l, with a weighted average for the concentrations (1.262 ± 0.402 mg/l), this results are higher than safe limit of 0.03 mg/l by WHO[6] and 0.019 mg/l by ICRP[7].
- 3) The concentration of uranium in these regions is relatively high, therefore, is advisable to treat them, by all ways, to protect the population of these areas from exposure to uranium.
- 4) The pollution ratio in a region (Towers high-pressure behind the Al-Tuwaitha nuclear site) and adjacent areas of uranium is the largest compared to other areas, which means that the population of these areas are more vulnerable to uranium from the other regions.

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