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Calculating uranium concentrations in some urine samples of cancer patients and comparing them with healthy people using the nuclear trace detector CR-39

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Abstract

This research aims to measure uranium concentrations in human urine samples from various patients with cancer using a nuclear trace detector CR-39. The study was conducted in Nineveh Governorate. In the study, several parameters have been considered, such as age, gender, and the place and number of doses taken by the patient. The samples were divided into two groups. Firstly, it was for patients with cancer, with 22 urine samples. Secondly, it was for healthy with non-cancer, with 15 urine samples. The findings demonstrated the presence of uranium contamination in all urine samples in both groups. Furthermore, it was found that cancer patients' urine samples were more contaminated with uranium than samples of non-cancer patients.

Keywords: Uranium, Urine, CR-39, Cancer patients.

Introduction

We live in a world where environmental radiation is everywhere. The light and heat resulting from nuclear reactions in the sun are essential to our existence. Where natural radioactive materials are found throughout the environment, our bodies contain radioactive substances, such as $carbon^{614c}$, $potassium^{1940k}$ and $lead^{84210pb}$ in a normal amount (IAEA, 2004). The spontaneous nuclear transformation of unstable atoms that leads to the formation of new elements is how radioactivity is described. Alpha particle absorption, beta particle emission, positron emission and orbital electron capture are some processes that describe these transitions. Gamma radiation may be used or not to accompany each interaction (Taylor et al., 1997).

The human body absorbs radionuclides in certain quantities. It is either because they come from continuous exposure to natural or man-made radiation sources (such as gamma rays, terrestrial sources and radon) or because it is naturally present in the human body since birth (explained later) (Brugge et al., 2005).

We must know that radionuclides such as uranium, thorium, and other isotopes reach the human body in three different paths (Bersina et al., 1995):

1. Inhalation: It is the most effective form of radioactive isotope absorption.
2. Ingestion: It includes drinking water, eating food, smoking cigarettes, etc.
3. The third is skin contact with radionuclides.

Usually, approx (5 Bq) uses to determine the total amount of $uranium^{.238U}$ that can be absorbed from the food that enters the human body (Poschl et al., 2006).

Among the sources of natural radioactivity are those that occur individually, Rubidium $(.87Ro)$ and Potassium $(.40K)$, which have a half-life of about $(4.8 \times 10^{10}\ years)$ and $(1.3 \times 10^{9}\ years)$, respectively (Ismail et al., 2010). As for the other part of radioactivity, it occurs in the form of chains. For example, the uranium chain, the thorium chain, the actinium chain, and the neptunium chain. The importance of these natural chains depends on: 1) their abundance in nature, 2) their half-life, and 3) the type of their emitted radiation (Eisenbud et al., 1997). For industrial radioactivity, it occurs through the industrial production of radionuclides by bombarding stable nuclides with charged particles or neutrons inside the nuclear reactor. The radionuclides produced that we benefit from in various research and industrial fields, such as nuclear explosions, the production of nuclear power, and medical uses (UNSCEAR, 2010).

Uranium is one of the radioactive chemical elements found in the periodic table. It is a heavy, silvery-white, toxic and radioactive metal. It decomposes emitting alpha particles $(\propto)$, with a decay constant of $(1.5 \times 10^{-10}\ years)$ (WHO, 2004). Uranium is also found in various quantities in nature in rocks, soil, water, air, plants, animals, the human body and other places (Al- Jumaili, 2002).

In this article, we used a solid-state nuclear trace detector CR-39 to calculate uranium concentrations in 45 different urine samples, including for patients with cancerous diseases and others for patients with other non-cancerous diseases in Nineveh Governorate. In each case, uranium concentration was calculated due to the exposure of this province to bombing, sabotage and warfare from 2003-2017. We counted the traces of fission fragments in the nuclear trace detector CR-39.

Materials and Methods

As mentioned earlier, this research aims to measure uranium concentrations of urine samples of patients with cancer and other diseases in different locations in Nineveh Governorate. Samples were collected from patients in August 2022 at the Oncology Hospital in Nineveh Governorate.

To calculate the uranium concentration, 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.

Then, the samples were classified into two tables. We used the technique of counting traces of fission fragments for uranium concentration. In this technique, 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 (Figure 1).

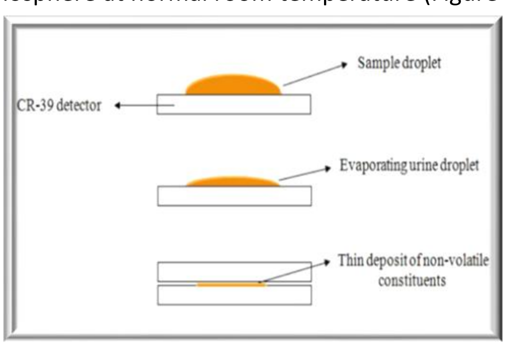

Figure 1: Formation of a thin deposit due to evaporation of the sample droplet (Alter, 1981).

Next, the detector piece is covered with another detector piece. Then, 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 $(3.02 \times 10^9 n\ cm^{-2}\ s^{-1})$. The used neutron source is Am-Be (Figure 2).

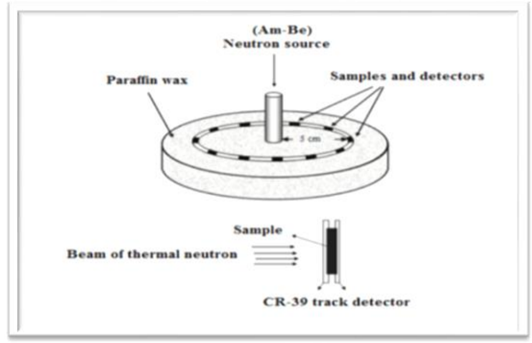

Figure 2: The irradiation of samples and the detectors to the neutron source (Al- Jumaili, 2002).

A standard uranium solution is prepared using urinal acetate $(cH_3\ coo)_2\ Uo_2$. Then, we used Equation 1 to get the fission that occurred on the detector (Berger, 1973):

$$92235U + 01n_{thermal} \rightarrow 92236U^* \rightarrow 56141Br + 3692Kr + 301n \quad (1)$$

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 five hours. The solution is prepared using a volumetric technique based on Equation (2) (Mohammed, 2014):

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

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

Next, the samples were subjected to microscopic examination, which represents the last step in the process of detecting traces, as it was viewed using a light microscope at a magnification $(10 \times 40\ X)$. Then, reading the traces per unit area using a special lens divided into several squares and calculating the average number of traces for each sample, then we find the density of traces from Equation (3)(Alter, 1981):

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

Results and Discussion

We measured the concentration of uranium in urine samples by comparing the density of traces recorded in the detector and the density of standard solutions, as shown in Equation (4) (Wrenn et al., 1992):

$$C_x = \left(\frac{P_x}{P_s}\right) . C_s \quad (4)$$

Cs and Cx represent uranium concentrations for the standard and unknown samples, respectively, in a unit (ppb). Ps and Px are the induced fission track density for standard and unknown samples, respectively, in a unit (tracks /mm^2).

We drew the graphical relationship between the trace density of the standard models and the uranium concentrations (Figure 3) (Battawy et al., 2012). Then, we calculated the unknown concentrations of uranium from the following relationship No. (5).

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

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

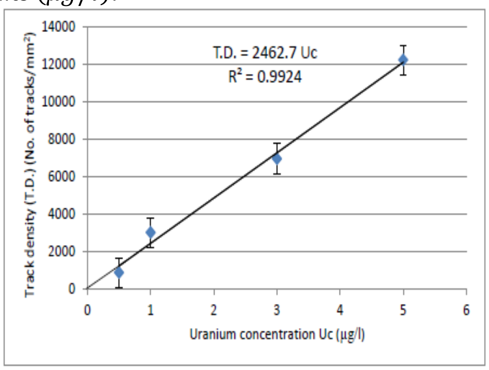

Figure 3: The relation of track density and uranium concentration in standard samples (Battawy et al., 2012).

Uranium concentrations are measured in 37 urine samples that covered several areas of Nineveh Governorate, using the technique of counting traces of fission fragments in the detector CR-39 resulting from the bombardment of uranium nuclei $92235U$ with thermal neutrons. Then, uranium is determined by approved calculations compared to standard samples as shown in (Figure 3).

Table 1 lists uranium concentrations for sick people with cancer, which was $(4.56\, \mu g/l)$ for a woman on the side of Zummar-Nineveh Governorate. This focus is because she had lung and thyroid cancer for more than (4 years), took many therapeutic doses, and drinks cigarettes. All these factors led to an increase in the percentage of uranium in her urine. The concentration of uranium varies from one person to another according to: age, gender, number of years of illness, in addition to the number of therapeutic doses taken by a patient with cancer. It is worth mentioning that the nature of the place significantly impacts increasing or decreasing the percentage. This concentration is considered high compared to the internationally permitted concentration (ICRP, 1995).

The lowest concentration of uranium is $(1.39\, \mu g/l)$. It belongs to a person from the center of Mosul (Nineveh Governorate). Compared to the rest of the patients with cancer, the reason for this low concentration is due to his being a recent patient with rectal tumor cancer and taking only two treatment doses. Additionally, he is young compared to the rest of the patients. Furthermore, the nature of the area inhabited by the person with the tumor and the absence of any industrial radioactivity in the area.

Table 2 illustrates uranium concentrations in urine samples taken from patients without cancer. The results ranged between $(0.84\, \mu g/l)$ for a patient (her age is 30 years) to $(1.68\, \mu g/l)$ for a patient of (his age is 69 years). The reason behind the difference in the uranium concentration in patients (who do not have cancerous diseases) is due to the differences in the following:

1. Age.
2. Gender.
3. The nature of the region.
4. The history of the disease.
5. Cigarette smokers.

From the comparison between the two tables, the first for patients with cancerous diseases and the second for those with non-cancer diseases, we noticed that the uranium concentration in people with cancerous diseases is much higher than that of people with non-cancer diseases. Furthermore, we noticed that smokers' uranium concentration is higher than non-smokers. Moreover, we found that when the patient's age increased, uranium concentration in the urine increased due to the inability of the kidneys to get rid of uranium deposits.

Table 1: Uranium concentrations for sick people with cancer.

No.	Age (year)	Gender	No. of doses	Smoking	Track density (Track/mm)	Uranium Concentration $(\mu g/l)$
1.	59	F	8	Non	4437.86	1.80
2.	41	M	20	S	7278.10	2.95
3.	57	M	25	S	7692.30	3.123
4.	56	F	22	S	11242.60	4.56
5.	39	M	2	S	4260.35	1.729
6.	56	M	1	S	5207.10	2.11
7.	53	M	3	S	4437.86	1.80
8.	51	F	16	Non	6627.21	2.69
9.	73	M	1	Non	5207.10	2.11
10.	41	F	7	Non	4023.66	1.63
11.	72	M	1	S	6923.07	2.81
12.	67	M	1	S	7278.10	2.95
13.	64	F	8	Non	5857.98	2.37
14.	48	F	30	Non	6508.87	2.64
15.	63	F	2	Non	6213.01	2.52
16.	36	M	1	Non	4615.38	1.87
17.	45	F	20	Non	8284.02	3.36
18.	34	F	1	Non	4852.07	1.97
19.	68	M	8	S	8047.33	3.26
20.	61	M	30	Non	8579.88	3.48
21.	39	F	3	Non	3431.95	1.39
22.	60	F	15	S	7396.44	3.00

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

Table 2: Uranium concentrations for sick people without cancer.

No.	Age (year)	Gender	Smoking	Track density (Track/mm^2)	Uranium Concentration $(\mu g/l)$
1.	31	F	Non	2366.86	0.96
2.	52	F	Non	2603.55	1.05
3.	66	F	S	3076.92	1.24
4.	42	M	S	2544.37	1.03
5.	30	F	Non	2071.00	0.84
6.	39	F	Non	2189.34	0.88
7.	50	F	Non	3017.75	1.22
8.	31	F	Non	2662.72	1.08
9.	72	M	Non	3786.98	1.53
10.	69	F	Non	3846.15	1.56
11.	32	M	Non	2603.55	1.05
12.	37	F	Non	2426.05	0.98
13.	69	M	S	4142.01	1.68
14.	53	M	S	3136.09	1.27
15.	44	M	Non	3017.75	1.22

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

Conclusions

In this paper, we measured uranium concentrations in human urine samples from various patients with cancer using a nuclear trace detector CR-39. The study was conducted in Nineveh Governorate. We used solid-state nuclear trace detectors because of several advantages: 1) It is one of the simple modern techniques, 2) It does not need complex devices, 3) It is inexpensive to study uranium concentrations, and 4) It can be used in conducting many researches and studies for large places. In summary, we make the following notes.

1. We found that the highest rates of uranium concentrations were in Table 1 because they were patients with cancerous diseases.
2. We noticed that the lowest rates of uranium concentrations were in Table 2 because the patients did not have cancerous diseases.
3. 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*.
4. The increase in uranium concentration with age is caused by increase dietary intake and the accumulation of uranium in the body.

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