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Measurement of Uranium Concentration in the Soil Samples by Using Solid State Nuclear Track Detectors (SSNTDs)

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ABSTRACT

The research aims to measure the uranium concentration of soil samples collected from different regions are located around the nuclear research center at Tuwaitha to a contamination ratio statement of these regions, which include agricultural residential regions as well as being the regions for livestock of all kinds. The nuclear track detector (CR-39) was used as a method to detect uranium of through calculations depended on comparison with standard samples . Results indicate that the uranium concentration ranged between (1.07 ± 0.46 ppm) and (4.20 ± 0.50 ppm) and with average weighted equal to (2.40 ± 0.22 ppm) , these results are within allowed limit that equals (11.7 ppm).
Keywords: Soil, Uranium Concentration, Contamination, CR-39 Detector, Tuwaitha, SSNTD

I. INTRODUCTION

Natural radiation has always been part of the human environment. Its main components are cosmic and cosmogenic radiation, terrestrial gamma radiation from natural radionuclides in rocks and soil, and natural radioactive substances in our diet and in the air we breathe[1].

Radionuclides are found in the environment as naturally occurring elements and as products or by-products of nuclear technologies, one of the most common radionuclides is uranium (U), all isotopes of uranium are radioactive, so it is very important their quantity to be under control [2].

Technique of the tracks count of the fission fragments was used for find the concentration of uranium in soil , because of its ease and accuracy in determining the emitting elements of the alpha particles even if the concentration is very small, the CR-39 detector is considered of the best detectors to record the tracks of alpha particles and nuclear fission fragments , that is because of the advantage of its high sensitivity and the efficiency[3, 4].

The research aims to determine the concentration of uranium in surface soil in the surrounding regions nuclear research center Al-Tuwaitha, and identify contaminated regions with uranium by using the solid state nuclear track detection technique.

A. Radiation in Soil

Soil is the upper part of the earth's crust and is formed as a result of rock deformation by complex physicochemical processes, which include weathering, decomposition and water movement, so the soil is the result of the action of weather and human activities on the crust rocks of the earth. The soil is naturally radioactive, because of the mineral content. The natural radioactivity may vary considerably from one type of soil to another[**5**] .

Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. Volcanic geographic structures as well as rocks that are rich in phosphate, granite and salt contain natural radionuclides like uranium-238, thorium-232 and potassium-40. When rocks are disintegrated through natural processes, radionuclides are carried in soil by rain and flows. In addition to the natural sources, soil

radioactivity is also affected from man-made activities[**6**] .

B. Natural Uranium

The natural uranium includes numerous isotopes, but the most important are three isotopes: ^{238}U, ^{235}U,^{234}U. All uranium isotopes are radioactive, as it is shown in Table (1) .

Table 1. shown the Natural uranium isotopes [**7, 8**]

Natural Uranium Isotopes (Alpha emission)			
Isotope	Natural abundance (%)	Half-life (in years)	Decay Energy (Mev)
$^{238}_{92}U_{146}$	99.284	4.46 billion	4.270
$^{235}_{92}U_{143}$	0.72	704 million	4.679
$^{234}_{92}U_{142}$	0.0055	245000	4.859

The nuclei of radioactive elements are unstable, meaning they are transformed into other elements, typically by emitting particles (and sometimes by absorbing particles)[**7**].

Uranium is toxic for both humans and animals for two basic reasons: as a heavy metal , it has toxic chemical effects, and as an alpha-emitter , it also has radioactive effects.

Exposure to uranium and its compounds can cause adverse health effects due to radiological hazard caused by absorption of radiation emitted from uranium and its decay products. Radiation exposure can originate either from external sources, e.g. an area contaminated with uranium from projectiles which missed their targets, or deposited uranium oxides released from damaged tanks as well as from internal sources, like uranium taken up by inhalation of UOx aerosols or ingestion of contaminated food or water [**9**].

C. Solid State Nuclear Track Detectors (SSNTDs)

Solid state nuclear track detector (SSNTD) is a widely used technique among the various known methods for detection of nuclear radiation . This method owes its popularity mainly to its simplicity, cost effectiveness and capacity to store permanent records. Although minerals and glasses have been tested as SSNTDs, the higher sensitivity of the plastic materials to many charged particles and ease of track development and evaluation has made plastic materials more popular as SSNTDs [**10**].

CR-39 (Polyallyl diglycol carbonate) is a commonly used solid state nuclear track detector (SSNTD). CR-39 detectors are widely used in different branches of sciences such as nuclear physics, radon dosimeter and radiobiological experiments [**11**] . It was discovered in 1978 by Cartwright, Shirk and Price. Its density is 1.32 $g.cm^{-3}$. The monomer is containing two of Allyl groups:

$$(CH_2 = CH - CH_2)$$

The chemical form for CR-39 may be written as $(C_{12}H_{18}O_7)$. It is illustrated in Fig. (1) [**12**].

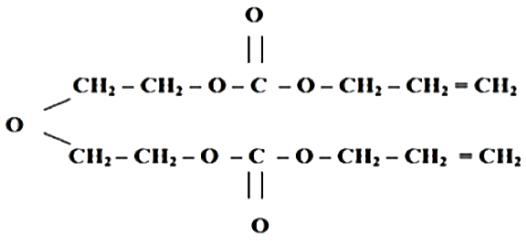

Figure 1. The chemical form of CR-39 detector [12].

The detector (CR-39) has a high efficiency to record the tracks in comparison with other detectors and it has some specifications as [**13**]:

1) Optically transparent
2) Very sensitive to radiation
3) Highly isotropic and homogeneous
4) Not cross-linking after radiation damage has broken the chemical bonds
5) Having a non-solvent chemical etchant
6) This polymer is resistant almost to all solvents, and to the heating Weak links of Carbon increase the sensitivity of the detector to radiation because it breaks easily when exposed to radiation. The lowest rate of charge can be detected in CR-39 [**12**].

II. METHODS AND MATERIAL

Soil surface samples were taken from different locations around the Tuwaitha nuclear research center in Iraq, as shown in Table (2).After collecting the samples, The samples were cleaned, placing each soil sample in an oven for drying at a temperature of 80°C for 2h until a constant weight was reached, The dried samples were grinded into a fine powder and passed through a standard mesh with size 75 µm . 0.5gm of soil samples was pressed into a pellet of 1cm diameter and 2mm thickness.

Table 2. shows the location and the coordinates (GPS) of the study samples

No.	code	Locations	Coordinates
1	S1	Taha mosque near square Salman	33°12'59.0"N 44°32'59.3"E
	S2		
2	S3	Stores of the Center for Research AL-Tuwaitha	33°13'15.9"N 44°32'22.7"E
	S4		
3	S5	Municipal Council from front of AL-Tuwaitha N.R.C.	33°13'12.3"N 44°31'31.3"E
	S6		
4	S7	Ibn Zahr hospital near AL-Tuwaitha Research Center	33°13'25.4"N 44°30'39.4"E
	S8		
5	S9	Beginning AL-Tuwaitha N.R.C.	33°13'19.6"N 44°30'40.7"E
	S10		
6	S11	End AL-Tuwaitha N.R.C.	33°12'14.3"N 44°29'42.3"E
	S12		
7	S13	Towers high-pressure behind the AL-Tuwaitha N.R.C.	33°10'55.7"N 44°30'01.5"E
	S14		
	S15		
8	S16	An agricultural area near to the high-pressure Towers	33°10'40.6"N 44°29'49.8"E
	S17		
9	S18	Al Bustan near the end of the AL-Tuwaitha N.R.C.	33°12'05.3"N 44°29'39.4"E
	S19		
	S20		
10	S21	Department liquefaction water near AL-Tuwaitha N.R.C.	33°12'54.5"N 44°30'17.5"E
	S22		
11	S23	Near a large mound of dirt AL-Tuwaitha N.R.C.	33°12'37.0"N 44°30'36.2"E
	S24		
	S25		
	S26		
12	S27	Jabir Ibn Abdullah Ansari neighborhood (farm A)	33°11'46.8"N 44°32'45.5"E
	S28		
13	S29	Jabir Ibn Abdullah Ansari neighborhood (farm B)	33°11'50.5"N 44°32'39.0"E
	S30		
14	S31	Jabir Ibn Abdullah Ansari neighborhood (farm C)	33°11'43.8"N 44°32'41.7"E
	S32		
15	S33	Jabir Ibn Abdullah Ansari neighborhood (farm D)	33°11'39.9"N 44°32'34.1"E
	S34		
16	S35	Ishtar region near AL-Tuwaitha N.R.C.	33°11'32.9"N 44°31'49.3"E
	S36		
17	S37	Al -Waredya region near AL-Tuwaitha N.R.C.	33°11'16.3"N 44°32'22.5"E

* (N.R.C) = Nuclear Research Center

The pellets were covered with (CR-39) detector as shown in Fig (2) and put in a plate of paraffin wax at a distance of (5cm) from the neutron source (^{241}Am-^{9}Be) as shown Fig. (3), with flux (10^5 n.cm^{-2}.s.$^{-1}$) and the fluence of thermal neutron ($6.048\text{x}10^{10}$ n.cm^{-2}) for (7 days), to obtain induced fission fragments according to the equation (1) :

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n(Thermal)} \rightarrow ^{236}_{92}\text{U}^{*} \rightarrow \text{f.f.} + (2 \rightarrow 3)^{1}_{0}\text{n} + \text{Q} \quad (1)$$

After irradiation CR-39 track detector and the samples, the chemical etching process to the CR-39 detectors has been done in order to show the fission tracks. This operation is for the use of sodium hydroxide solution NaOH as an etchant solution, with normality (6.25N) and temperature (60°C) for (3.5 hours) as the most favorable conditions. After the etching time (3.5h), the detectors have been removed from the etchant solution by forceps and washed with distilled water and then dried.

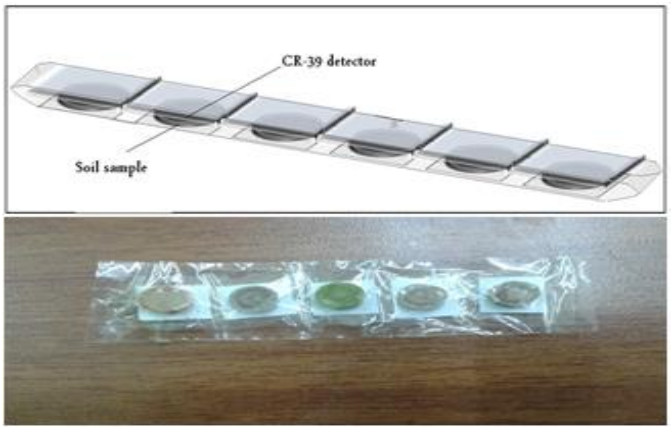

Figure 2. The pellets are covered with (CR-39) detector

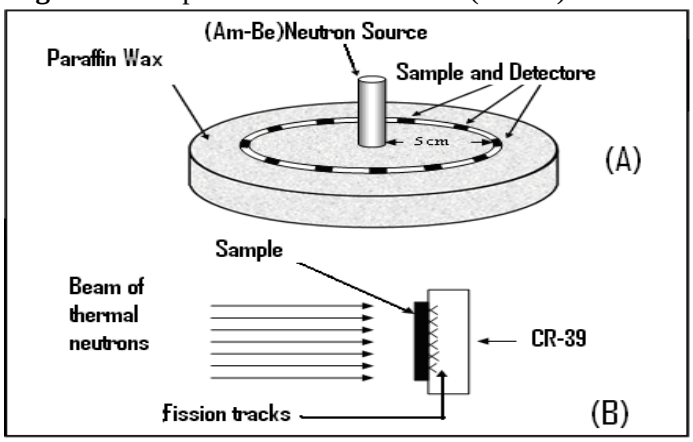

Figure 3. The irradiation of the detectors and samples by the neutron source.

I. Calculations

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 track of nuclear fission fragments and alpha particles on the surface of the detector, the track density was calculated by using the following equation [**14**]:

$$\text{Tracks density } (\rho) = \frac{N_{ave}}{A} \quad (2)$$

Where:

N_{ave} : Average number of total pits(track).

A : Area of field view.

An example of the photograph of observed tracks with th samples is shown in Figure (4).

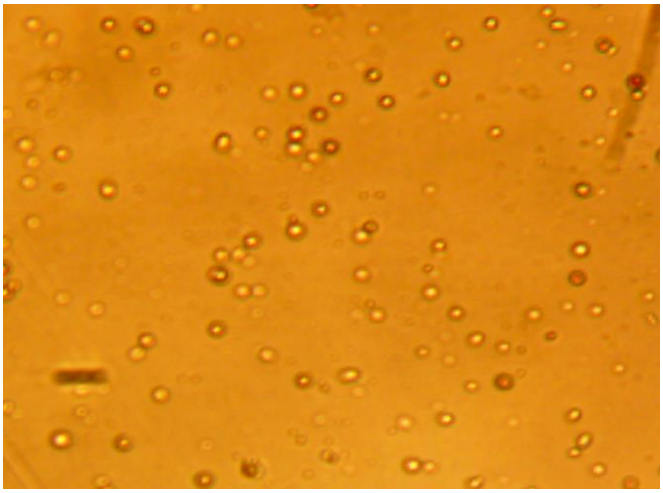

Figure 4. photograph of tracks in a soil sample corresponding to one location.

The uranium concentration in the soil samples was measured by comparing between track densities registered on the detectors of the sample pellet and that of the standard geological sample pellets according to the relation [**14**]:

$$C_X = C_s(\rho_x / \rho_s) \quad (3)$$

$$Cx = \rho_x / \text{slope} \quad (4)$$

Where:

C_X : Uranium concentration in unknown sample (ppm).

C_s : Uranium concentration in standard sample (ppm).

ρ_x : Track density of unknown sample(tracks/mm^2).

ρ_s : Track density of standard sample(tracks/mm^2).

The fig. (5) Shows of the relation between uranium concentration and track density in standard sample of the soil.

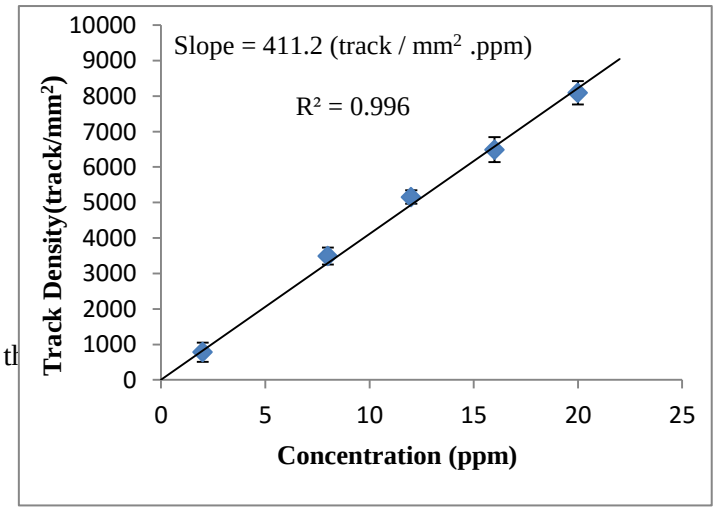

Figure 5. The relation between track density and uranium concentration (ppm) for standard soil samples.

III. RESULT AND DISCUSSION

In this research, the soil samples were used from surrounding regions of the nuclear research center at Tuwaitha to know the extent of contamination of these regions with uranium, uranium concentration has been calculated by using technique of counting the tracks of nuclear fission fragments using nuclear track detector (CR-39), and the results were arranged in the Table (3). The selection of these regions to measure the ratio of uranium, depending on several factors, the most important are:

1) Because this regions are surrounding the Tuwaitha nuclear research center, which contained several nuclear reactors.
2) Because of the nuclear research center at Tuwaitha was looted by some population during the war in Iraq.

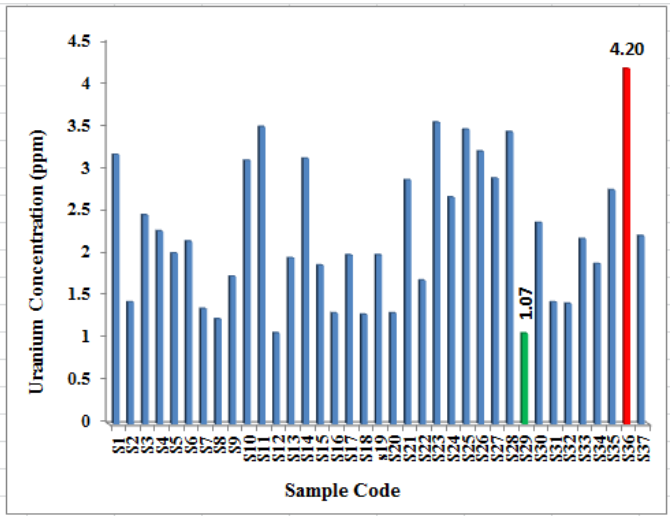

Figure 6. the concentration of uranium in the soil samples.

Therefore, it was necessary to monitor the level of pollution in those regions for estimating the dangers arising from pollution and processed as quickly and the best ways to ensure the safety of the population. Through the table (3), we find that the concentrations of uranium in soil samples ranging from (1.07 ± 0.46 ppm) in the sample (S29), which located in the region (Jabir Ibn Abdullah Ansari neighborhood (farm B)) and (4.20 ± 0.50 ppm) in the sample (S36), which located in the region (Ishtar region near AL-Tuwaitha N.R.C.) , and a weighted average equal to (2.40 ± 0.22 ppm). These results are within allowed limit, which is equal to (11.7 ppm)[**15**], the figure (6) shows the relationship between the uranium concentration and the sample code.

Table 3. Results of the uranium concentration in the soil samples.

No. Locations	Sample code	Tracks density (track/mm^2)	Uranium concentration (ppm)
1	S1	1308.9 ± 322.8	3.18 ± 0.79
	S2	593.0 ± 179.1	1.44 ± 0.44
2	S3	1016.1 ± 454.7	2.47 ± 1.11
	S4	937.5 ± 118.8	2.28 ± 0.29
3	S5	830.4 ± 448.2	2.02 ± 1.09
	S6	887.5 ± 385.4	2.16 ± 0.94
4	S7	560.7 ± 510.8	1.36 ± 1.24
	S8	510.7 ± 180.1	1.24 ± 0.44
5	S9	717.9 ± 265.4	1.75 ± 0.65
	S10	1280.4 ± 175.0	3.11 ± 0.43
6	S11	1444.6 ± 274.1	3.51 ± 0.67
	S12	442.9 ± 163.0	1.08 ± 0.40
7	S13	807.1 ± 339.7	1.96 ± 0.83
	S14	1291.1 ± 179.6	3.14 ± 0.44
	S15	771.4 ± 332.0	1.88 ± 0.81
8	S16	539.3 ± 258.5	1.31 ± 0.63
	S17	821.4 ± 399.8	2.00 ± 0.97
9	S18	532.1 ± 326.3	1.29 ± 0.79
	S19	821.4 ± 229.8	2.00 ± 0.56
	S20	539.1 ± 261.9	1.31 ± 0.64
10	S21	1185.7 ± 340.7	2.88 ± 0.83
	S22	698.2 ± 380.0	1.70 ± 0.92
11	S23	1466.1 ± 120.1	3.57 ± 0.29
	S24	1101.8 ± 191.8	2.68 ± 0.47
	S25	1432.1 ± 302.4	3.48 ± 0.74
	S26	1325.0 ± 157.4	3.22 ± 0.38
12	S27	1194.6 ± 363.7	2.91 ± 0.88
	S28	1419.6 ± 180.4	3.45 ± 0.44
13	S29	440.8 ± 189.2	1.07 ± 0.46
	S30	978.6 ± 132.2	2.38 ± 0.32
14	S31	592.9 ± 356.0	1.44 ± 0.87
	S32	585.7 ± 171.2	1.42 ± 0.42
15	S33	900.0 ± 485.4	2.19 ± 1.18
	S34	778.6 ± 507.3	1.89 ± 1.23
16	S35	1137.5 ± 359.7	2.77 ± 0.87
	S36	1726.8 ± 204.1	4.20 ± 0.50
17	S37	914.3 ± 330.0	2.22 ± 0.80
Weighted average			**2.4 ± 0.22**
Allowed limit [15]			**11.7**

IV. CONCLUSION

1) The highest concentration of uranium in the soil samples was in the sample (S 36) which is equal to (4.20 ± 0.50 ppm), this value is less than the allowed limit, which is equal to (11.7 ppm).
2) The pollution ratio in the region (Ishtar region near AL-Tuwaitha N.R.C.) with uranium is the highest in the comparison with other regions, and this means that the people of this region are the most vulnerable to uranium from the other regions.
3) The uranium contamination ratio in (Ishtar region near AL-Tuwaitha N.R.C.) and the region (Near a large mound of dirt AL-Tuwaitha N.R.C.) despite being within allowed limit, but it is the ratio cannot be underestimated, the uranium ratio is relatively high, so it is advisable to processed with all means to ensure the safety of the population from continuous exposure to uranium, while the rest of the proportions of the other regions are reasonable proportions.

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