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Uranium Concentration in Soil of some Eastern Iraqi Regions using Nuclear Track Detector (CR-39)

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ABSTRACT

The concentration of the natural uranium (U) varied from region to anther according to geological structure and to the accumulated amounts of fertilizer, which used in agriculture. Al-Fallujah is one of the major cities in Al-Anbar Governorate belonging to the Iraq, exposed to DU. Therefore, this work dedicated to measure the concentration of U in the soil of Al-Fallujah city.28 soil samples collected from the districts of Al-Fallujah city were measured against U concentration using CR-39 detector. Each sample was taken from three different depths; 15, 30, and 45 cm, to study the distribution of U in soil. The results showed that the maximum values of the specific activity (S.A) of U were 45.52, 37.29, and 27.22 Bq/kg, and the minimum values were 8.97, 10.62, and 4.44 Bq/kg, for the three depths, respectively. Whereas, the average values were 31.98, 22.30, and 15.55 Bq/kg, respectively.

Keywords: The uranium concentration, nuclear track detector (CR-39), soil

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INTRODUCTION

Naturally existing radiation are the major contributors to the radiation environment. These radiations are cosmic rays and terrestrial radiations (Kathren, 1998).

The movement of radionuclides in the environment has been studied for many years, with the principal objective of tracing the routes by which they accumulate in the food chain and become available for human consumption. In addition; Fukushima accident in 2011 represents a live example about the effects of radiation on human (World Nuclear Association, 2012).

Radionuclides which occur in the environment have a pattern of distribution which is in dynamics equilibrium, with disturbances due to cultivation, earth movement and weathering. This equilibrium has had superimposed upon the isotopes, some with comparatively short – lives, which have disturbances allow the treating of pathways through which the radio nuclides are dispersed.

The terrestrial radiations are produced from (1) Cosmogenic radionuclides, which are being produced by the cosmic rays, and (2) primordial radionuclides, which have been present since the earth was formed.

The primordial radionuclides are very long lived. The life of the earth is assumed to be 4.5 billion; therefore the short – lived radionuclides would have decayed by this time. The radionuclides of half–life of the order 10^8 years are present in certain amounts at this time. The relatively more abundant naturally occurring radionuclides belong to uranium and thorium decay series. One of the decay products of these series is the radioactive radon gas. In addition to the nuclides of the decay series, an important naturally occurring radionuclide is ^{40}K (Dinh Chau, 2011). Uranium is a naturally occurring element found in low levels within all rock and soil. This is the highest-numbered element to be found naturally in significant quantities on earth. According to the United Nations Scientific Committee on the Effects of Atomic Radiation, the normal concentration of uranium in soil is 300 μg/kg to 11.7 mg/kg (UNSCEAR 1993). All uranium isotopes are radioactive. The three natural uranium isotopes found in the environment, U-234, U-235, and U-238, undergo radioactive decay by emission of an alpha particle accompanied by weak gamma radiation. The dominant isotope, U-238, forms a long series of decay products that includes the key radionuclides radium-226 and radon-222. The decay process continues until a stable, non-radioactive decay product is formed. The release of radiation during the decay process raises health concerns.

There are many authors were studied the concentration of U in Iraq; In 2011, Tawfiq et al. measured the uranium concentrations in soil of Thi-Qar, Basra and Baghdad Governorates using CR-39 detectors. The uranium concentrations were 16.38, 16.1 and 0.78 in Thi-Qar, Basra and Baghdad, respectively (Tawfiq et al, 2011).

In 2011, Al-Ani et al. estimated uranium concentrations in the soil of some area in Missan Governorate - Iraq (Al-Iskan area, Al- Shibbana area, Hai- Al Moualimin Al Jadied area, Sector 30 area). The averages of uranium concentrations in soil samples were 2.765±0.404 for Al-Iskan area, 1.719±0.432 for Al- Shibbana area, 2.320±0.236 for Hai Al- Moualimin Al- Jadied area and 2.158±0.631 for Sector 30 area (Al-Ani et al, 2011).

The aim of the work is measuring the uranium concentration in soil for Al-Falluja city for different depths (to study the diffusion of U in soil with time) using CR-39 detector and compared their values with the national and international allowed limits.

THE STUDIED AREA

Al-Fallujah is a city in the Iraqi province of Al Anbar, located at 69 km west of Baghdad on the Euphrates. Al-Fallujah city grew from a small town in 1947 to a population of 326,471 within Iraq; it lies in a strategic position at a junction between the Iraqi Capital; Baghdad and Al–Inbar Governorate. This city stands at an elevation of around 40 meters above sea level.

Soil Sampling

There are four general steps involved in soil sampling (IAEA, 2004). Documenting and designing a suitable soil sampling plan for the determination of the level of uranium in the soil, are vital steps in soil sampling.

The first and most important section in documenting a sampling plan is stating clearly the measureable objectives (Carter Martin, 1993) and for developing sampling plans in order to provide useful data from the collected soil samples.

Systematic grids sampling is a scheme in which selected units are at regular distance from each other and attempts to guarantee a complete coverage of the soil population. The sampling points were identified by subdividing the total area of Al-Fallujah city using a square grid and collecting samples from the intersections of the grid lines. However, the residential districts of Al-Fallujah represent, approximately, good distribution for the sampling points. Furthermore, the origin and direction for placement of the grid was done using an initial random point located at the extreme east point of the entirely investigated area. From this point, the coordinate axis and grid was constructed over the whole area. Fig.1-a illustrates a systematic grid sampling approach.

In some cases, when the selected sampling points were found to locate at commercial or private constructions, or could not be physically reached, a systematic random sampling approach was found to be a flexible alternative. The area of concern was subdivided using a square grid as described in systematic grid sampling. The sampling points were shifted during the field visit from within 1.5 to 2.5 km of the intended selected points to the nearest representative points. This approach was found to be useful for estimating the average concentration within specific grid cells. The soil samples were collected from each cell using the random sampling approach. Fig.1- b illustrates a systematic random sampling approach.

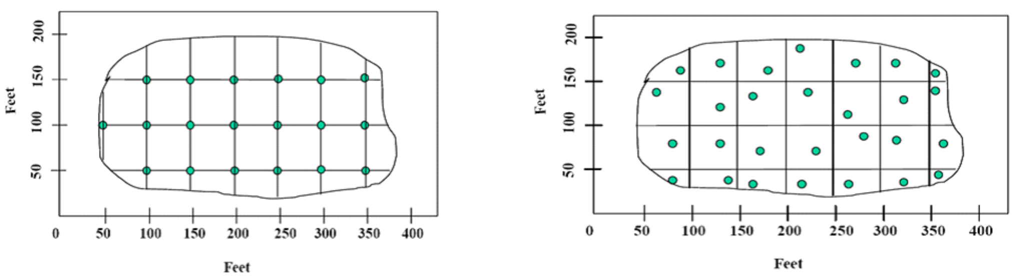


Fig.1: (a): A systematic grids sampling approach. (b): A systematic random sampling approach (Eappen and Mayya, 2004)

Random sampling may be used as well within the specific area of concern. The sampling points should be selected randomly and independently (Eappen and Mayya, 2004). Fig.2 illustrates a random sampling approach. Collecting random samples is necessary in order to make probability or confidence statements about the sampling results. A random sampling approach is suitable for the areas where the site is suspected to be homogeneous with respect to the parameters to be monitored (Eappen and Mayya, 2004).

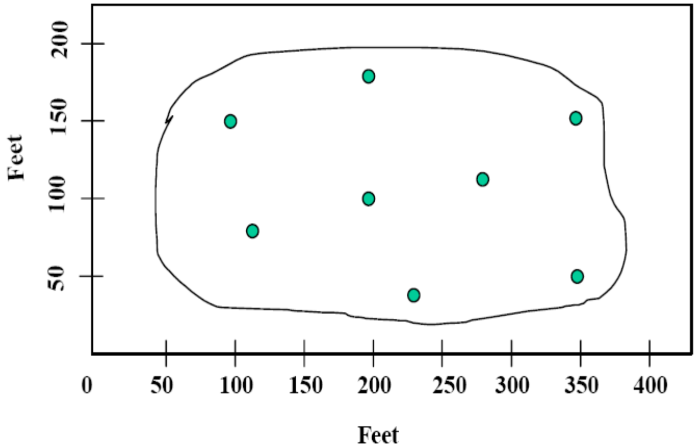


Fig.2: Random sampling approach

However, the typical, regular sample location was chosen to be approximately 5 km apart. Thus, the total sample size amounted to approximately 28 cores from across Al-Fallujah city. A map of Al-Fallujah city was illustrated in Fig.3.

The soil samples measured in the current work were collected from sampling points which were located at regular intervals represent the districts of Al-Fallujah city. Table (1) shows theses sampling points.

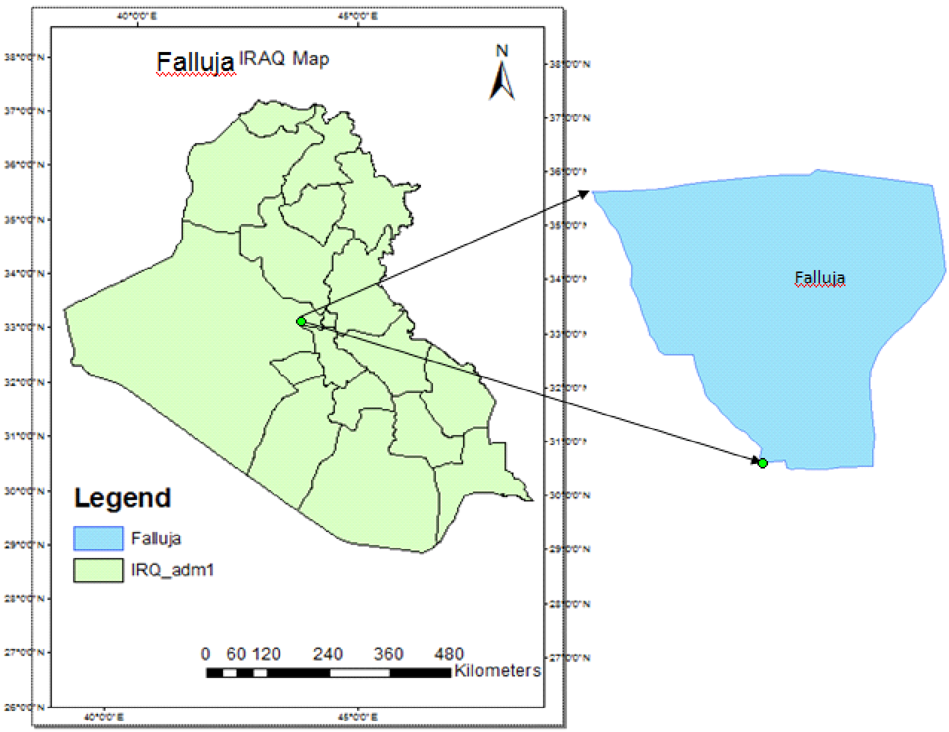


Fig.3: The map of Al-Fallujah

Table 1: The representation and details of the soil samples

Sample	*Details*
S1	Hai Al-Alasskree (Al-Husian Mosque)
S2	District officers (general hospital)
S3	District Police (Company)
S4	Aljughaifi district (mosque Martyrs of Fallujah)
S5	The second district teachers (Al-Takyaa street)
S6	Neighborhood unity (Behind Al-takyaa street)
S7	Jolan neighborhood (Dispensary Golan)
S8	Neighborhood Albzazh (Public Garden)
S9	Andalus neighborhood (Farouq Mosque)
S10	Neighborhood message (Jama Ali bin Abi Talib)
S11	Green neighborhood (School alhomam)
S12	Nazzal neighborhood (School Leader)
S13	Mutassim neighborhood (School of Alanbar)
S14	Industrial district (Rubaie flour plant)
S15	Shuhada neighborhood second (Mosque senders)
S16	Green neighborhood (School Fattouh knowledgeable)
S17	Secand Shuhada neighborhood (Control Nuaimiya)
S18	Industrial district (Street forty)
S19	Neighborhood message (Mosque Paradise)
S20	Neighborhood Gomhoureya (Teachers Association)
S21	Neighborhood Bzazh (Public Library)
S22	Neighborhood Officers (Youth center)
S23	Andalus neighborhood (Junior Islamic Studies)
S24	First Shuhada neighborhood (Cemetery Amoadida)
S25	District engineers (Gas Plant)
S26	Tamim neighborhood (Mosque of Taqwa)
S27	Neighborhood message (School Khalil)
S28	District military (Control staff)

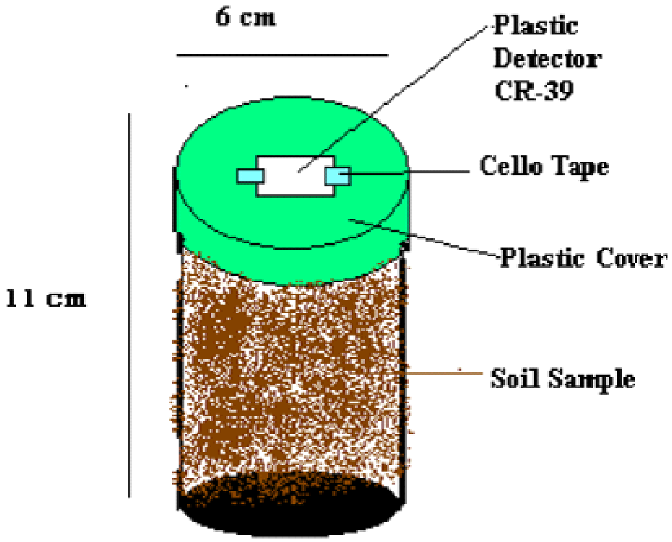
EXPERIMENTAL WORK

The CR-39 detector is one of the most versatile, sensitive, and widely used SSNTD now a days. It has been recognized by Cartwright and his colleagues as a track detector since 1978 (Cartwright et al, 1978). CR-39 is an abbreviation of Columbia Resin-1939 (Tommasino, 1997). It is an amorphous polymer consisting of short poly-allyl chains joined by links containing carbonates and diethyleneglycol groups (Fujii, 1995) into a dense three dimensional network with an initiating monomer unit (Singh and Prasher, 2004). A study of the performance of different laboratories in international inter-comparisons of passive radon detectors showed that poly-allyldiglycol carbonate (CR-39) could be used to make accurate measurements.

The CR-39 detector is very sensitive for the detection of α-particles. The detector etched at 70 ± 1^0C for a period of about 4–10 h in 6.25 N NaOH solutions, and used in neutron, heavy ion and uranium and radon dosimetries.

In this method, one must use a standard source with known concentration of uranium and by plotting a calibration curve, the concentration of uranium can be estimated. The

disadvantage of this method is the need to the uranium standard source with concentration close to the concentration of the tested sample and with the same physical properties.
The calibration of the uranium concentration was done by measured the density of tracks in the CR–39 films which were putted for one month in standard samples of uranium taken from. Fig.4 illustrates the calibration curve for soil measurements and from curve fitting; one can be deduced equation (1) which used to estimate the results of the Uranium concentration in soil samples.
The soil samples are placed in a plastic cup with plastic cover, the diameter of the cover equal 6 cm and the height of the cup is 11cm as shown in Fig.4, the CR-39 detector is fixed inside the cover facing the soil sample.



In order to collect soil samples of appropriate volume and mesh size, the following procedures were followed:

- A total of at least 1.5 – 2 kg of soil was collected at 15 to 45 cm depth (three samples) levels at each spot, with an extended surface of 15 cm, using shovel and scoop. Since the presence of extraneous materials which are not relevant for the soil samples may introduce an error in the analytical results (Eappen and Mayya, 2004), glass pieces, twigs, stones, or leaves were eliminated from the soil samples. Each sample was transferred first to a 2 mm sieve fitted in a collecting pan.
- The post-sieved samples were then filled into labeled polyethylene bags and sealed. The information of each sample was documented separately in prepared labels and stuck with a waterproof, tape on each sample bag. The labels included soil information such as; sample ID, depth level, sampling date, and any other pertinent remarks.
- Before leaving the sample location, the sample information, along with any remarks related to, the sample's collection, volume, depth, the soil's condition, general observations and difficulties were documented carefully in the field notebook.

These steps were repeated for all the collected samples taking into consideration cleaning the sampling tools before collecting each new sample by the soil itself of the new location to prevent soil-to-soil contamination.

RESULTS AND DISCUSSION

United Nation Environment Program (UNEP) proved that uranium can diffuse into soil with 15cm for 8years. Therefore, uranium concentration (UC) was measured for three different depths of soil samples collected from 28 districts of Al-Fallujah city. Table (2) presents the results of UC and the specific activity (S.A) of uranium for 15, 30, and 45 cm depths. The results show that the maximum values of S.A were 45.52, 37.29, and 27.22 Bq/kg, and the minimum values were 8.97, 10.62, and 4.44 Bq/kg, respectively. Whereas, the average values were 31.98, 22.30, and 15.55 Bq/kg, respectively. The maximum value of the average of sum of the three depths was 33.78 Bq/kg, while the minimum was 9.92 Bq/kg. The overall average of sum of the three depths was 23.27 Bq/kg.

These results strongly suggested that Al-Fallujah exposure to uranium (or Depleted Uranium DU as bombs) because of S.A results of uranium decreases with depths and the soil samples were taken from residential areas and not from agriculture areas that may be contained fertilizers, which in turn contains uranium. However, Figs. 6, 7 and 8 show the histograms of S.A of uranium as a function of the investigated district. Fig.9 illustrates the percentage ratio between S.A of first and second depths (the black histogram) and S.A of the first and third depths (the red histogram). It is clear from this figure that the S.A of the first depth is larger than the second, which in turn larger than the third.

Besides, although the results indicate the rising in S.A of uranium in Al-Fallujah soils, the national and international comparisons proved that S.A of uranium is still in the allowed limits. These conclusions can be seen from Table (3) for national comparison and from Table (4) for international comparison.

Hence, the results show that this urban area is safe as for as the health hazards of uranium are concerned.

Table (2): UC and the specific activity of U for soil samples for three different depths (A= 15 cm; B = 30 cm; C = 45 cm)

Sample's Code	*CU (ppm)*	*Specific Activity (Bq/kg)*
S1A	0.72	8.97
S1B	1.32	16.34
S1C	0.36	4.44
S2A	0.95	11.76
S2B	1.00	12.45
S2C	1.18	14.69
S3A	2.16	26.77
S3B	1.35	16.70
S3C	1.89	23.43
S4A	2.56	31.80
S4B	0.86	10.62
S4C	1.66	20.54
S5A	2.64	32.71
S5B	2.20	27.22
S5C	1.09	13.50
S6A	3.21	39.85
S6B	2.20	27.22
S6C	1.94	24.11
S7A	3.30	40.95

S7B	1.46	18.07
S7C	1.16	14.41
S8A	3.47	43.00
S8B	3.01	37.29
S8C	1.70	21.05
S9A	2.85	35.32
S9B	2.34	28.96
S9C	2.05	25.39
S10A	2.69	33.40
S10B	2.11	26.17
S10C	0.72	8.93
S11A	2.64	32.71
S11B	2.50	31.02
S11C	1.83	22.65
S12A	2.48	30.70
S12B	2.03	25.16
S12C	1.42	17.62
S13A	3.67	45.52
S13B	1.83	22.65
S13C	0.98	12.13
S14A	2.56	31.80
S14B	1.35	16.70
S14C	1.46	18.07
S15A	2.99	37.06
S15B	2.56	31.80
S15C	2.20	27.22
S16A	2.03	25.16
S16B	1.46	18.07
S16C	0.98	12.13
S17A	3.67	45.52
S17B	2.20	27.22
S17C	1.05	13.00
S18A	2.90	35.91
S18B	2.49	30.93
S18C	1.97	24.48
S19A	2.93	36.37
S19B	1.79	22.19
S19C	0.83	10.30
S20A	1.83	22.65
S20B	1.38	17.16
S20C	1.09	13.50
S21A	2.20	27.22
S21B	1.64	20.36
S21C	1.01	12.49
S22A	2.33	28.87
S22B	1.46	18.07
S22C	1.09	13.50

S23A	2.76	34.27
S23B	1.83	22.65
S23C	1.18	14.60
S24A	2.03	25.16
S24B	1.53	18.99
S24C	0.72	8.93
S25A	2.89	35.87
S25B	2.08	25.85
S25C	1.09	13.50
S26A	2.07	25.62
S26B	1.64	20.36
S26C	0.79	9.84
S27A	2.45	30.42
S27B	1.24	15.33
S27C	0.59	7.32
S28A	3.22	39.94
S28B	1.51	18.76
S28C	1.09	13.50

Table (3): The activity concentration of uranium in soil samples in some areas of Iraq

No.	Average	S.A of U in Bq/kg	Regional and year
1	Al-Rumela city in Iraq (1996) (Tawfiq, 1996)	71.98	12.77 – 131.19
2	Some districts in Baghdad (Karim, 2004)	53.57	41.42 – 65.72
3	Karbala/ Iraq (Al-Baidhani, 2006)	22.32	22.32
4	Wasit (Al- Wasity, 2010)	18.29	13.76 – 22.82
5	Missan (Al-Ani et al, 2011)	27.81	21.32 – 34.29
6	Thi – Qar (Tawfiq et al, 2011)	20.31	20.31
7	University of Baghdad – Al-Jadiriyah Site (Al-Ani et al, 2011)	18.67	18.67
8	Iraq – Al-Fallujah*	23.27	9.92- 33.78

* Present study

Table (4): Summary of activity concentrations of uranium in soil samples in some of the world regions (Abdi et al, 2008; Kaltofen and Carpenter, 2005; Golas **et al 2005;** Mohsen et al, 2007)

Region	S.A of Uranium (Bq/kg)	
	Range	Average
China	2-690	33
Hong Kong	25–130	84
India	7–81	29
Japan	2-59	29
Kazakhstan	12-120	37
Malaysia	49–86	66
Thailand	3-370	114
USA	4–140	35
Syria	10-64	23
Turkey	7-200	21

Pakistan	25–28	26
Egypt	6–120	37
Croatia	83-180	110
Greece	1–240	25
Portugal	26-82	49
Russia	0–67	19
Arab Gulf (Iranian side)	21–65	41
Iraq- Al-Fallujah*	9.92 – 33.78	23.27

* Present Study

CONCLUSIONS

According to the results, some remarkable conclusions can be listed;

- The concentrations of U decrease with increasing depth of investigated soil, which may be attributed mainly to the hostilities of the 1st and 2nd Golf wars.
- Although the results indicate the rising in the concentration of U in Al-Fallujah soils, the national and international comparisons proved that concentration of U is still in the allowed limits. Therefore, the results show that this urban area is safe as for as the health hazards of uranium are concerned.

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