Proceedings of the Pakistan Academy of Sciences: A Physical and Computational Sciences 61(4): 317-323 (2024)

ISSN (Print): 2518-4245; ISSN (Online): 2518-4253
http://doi.org/10.53560/PPASA(61-4)677

Pakistan Academy of Sciences

Research Article

Measurement of Uranium Concentrations in the Soil Samples of Nineveh Province, Iraq Using CR-39 Detector

Malik H. Kheder* and Hanaa N. Azeez

Department of Physics, College of Education for Pure Sciences,
University of Al-Hamdaniya, Nineveh, Iraq

Abstract: The physiological influence of radiation, which may induce cancer, makes the radioactive field vital to human health. Radon, which is hazardous to both humans and the environment, is deposited in soil via uranium decay. Extended exposure to elevated levels of alpha radiation, primarily radon, causes lung cancer. Thus, research is necessary to observe how the levels of human exposure vary. In evaluating natural exposure radiation, it is essential to control the quantity of radionuclides in the soil by determining the radioactivity level from these sources. Twenty samples of soil from different places in the Nineveh province in northern Iraq were analyzed for uranium content by the CR-39 nuclear track detector. These samples had radon concentrations ranging from 27.221 to 59.407 $Bq.m^{-3}$, and the mean is 38.917 $Bq.m^{-3}$. This mean value is below the level of reference limits 100 $Bq.m^{-3}$ of the World Health Organization (WHO). Uranium levels ranged values from 0.129 to 0.281 ppm, with a mean of 0.182 ppm. Findings demonstrate that the natural radiations in the region are within the permissible range, as shown when comparing the results to global averages, the uranium concentration levels fell below the average of global value 2.8 ppm, and below the acceptable limit of 11.7 ppm.

Keywords: Nineveh Province, Soil Samples, Uranium Concentrations, CR-39 Detector, Radon Concentrations.

1. INTRODUCTION

Soil is a major natural source of radioactivity because of its mineral richness. It also makes people more vulnerable to radiation and helps release radioactive materials into the environment. For these reasons, soil's inherent radioactivity is thought to be a key sign of radioactive contamination [1]. The concentration of radionuclides in soil is the primary indicator of natural background radiation [2]. The natural radioactivity can differ significantly across different types of soil. Natural occurring radioactive elements (NORMs) are present in soil and the environment. These elements are the released nuclear radiation from naturally occurring radionuclide materials. Uranium is one of these radionuclides that is produced by nuclear technology [3]. Similar to other minerals, uranium is an element naturally occurring that has existed since the beginning of the earth. Since each uranium isotope is radioactive, its quantity needs to be controlled [4]. It turns into a non-radioactive lead as it decays, releasing alpha particles. A progeny, also known as a decay product, is a new radionuclide that occurs along the decay chain. It adds approximately seven times as much radioactivity to the soil as uranium does. In rocks and soil, The closest source of radium and radon is uranium. One of the primary causes of background radiation is radon, a uranium derivative [5]. Because of its chemical and radioactive characteristics, uranium that accumulates in people may have two effects. Humans may suffer negative consequences from consuming large amounts of uranium and the byproducts of its decay. The Harmful effects on humans are caused by high uranium intake and by-products of its decay. Exposure to naturally soluble uranium of 0.1 mg/kg causes chemical temporary kidney damage [6]. Primordial radionuclides enter the soil through the weathering of the earth's crust. It took the radionuclides in the soil by plants up through their roots and passed them on to humans when crops are consumed, resulting in internal

Received: April 2024; Revised: November 2024; Accepted: December 2024
* Corresponding Author: Malik H. Kheder <malik.19732013@yahoo.com>

exposure to ionizing radiation. Radionuclides consumed through food are major radiation pathways for health long-term considerations, significantly contributing to average doses of radiation to different human body parts and tissues The primary uranium and radium deposition sites are the kidneys, liver, and bones [7]. The uranium amount in the soil varies greatly depending on the geological region; it can range from 0.1 to 20 ppm [8], with a global average of 2.8 ppm and 11.7 ppm being the permitted limit [9, 10]. The plastic CR-39 detector was used to measure The amount of uranium present in soil, due to the great sensitivity of CR-39 to alpha particles of low energy. These tracks are examined under a microscope following the etching procedure to magnify them [11]. The goal of the research is to identify the precise uranium content in twenty samples of soil from the Nineveh province in Iraq.

2. MATERIALS AND METHODS

Twenty samples of soil were gathered in the Iraqi province of Nineveh from various places as in (Figure 1). The samples were taken 30 cm below the surface. The samples were sieved using a 0.2 mm mesh and baked for 24 hours at 100 °C. After that, samples were placed inside a uranium dosimeter, which was covered with plastic tape to keep radionuclides from escaping into the atmosphere (Figure 2). Utilizing a radioactive uranium dosimeter, solid-state track detector techniques were employed in the measurements. Each container has a 7 cm diameter and a height of 10 cm. It holds one CR-39 detector (1 x 1) cm^2. Upon arriving at the detector, alpha particles leave traces. The average concentration of radon is directly correlated with the number of tracks. A sample of 50 g in a cylindrical plastic container (uranium dosimeter) was placed with its back to the CR-39 detector. The sample is 3 cm in height and 7 cm from the detectors to the sample surfaces, closed for 60 days. Detectors were removed after 60 days, and the tracks were revealed by the NaOH etching at normality 6.25 N in the water bath at 70 °C heated. Detectors were cleaned and then tracks were tallied using a microscope at 400x magnification. The following formula is used to calculate track densities [12].

ρ = (The tracks number)/(The field of view area) (1)

The track density ρ(in track.cm^{-2}) in sample air space is related to the exposure duration T(in a day), and then concentrations of radon CRn (Bq.m^{-3}) can calculated using the relation [13].

$$C_{Rn} = \rho/KT \quad (2)$$

To calculate the radon concentration, the track density of the detector ρ(track.m^{-2}) was used. The radon concentration C_{Rn}(Bq.m^{-3}) during the period of irradiation t(s) is connected to the density of tracks, or total tracks number per area of the detector's field of view via microscope, utilizing the sensitivity of detector K(m), as in the equation (2). The sensitivity K in a unit of (m) is defined as the density of track per exposure unit of (Bq.s.m^{-3}). From equation (2), the unit $K = (\text{track}.m^{-2})/(\text{Bq}.\text{s}.m^{-3})$.

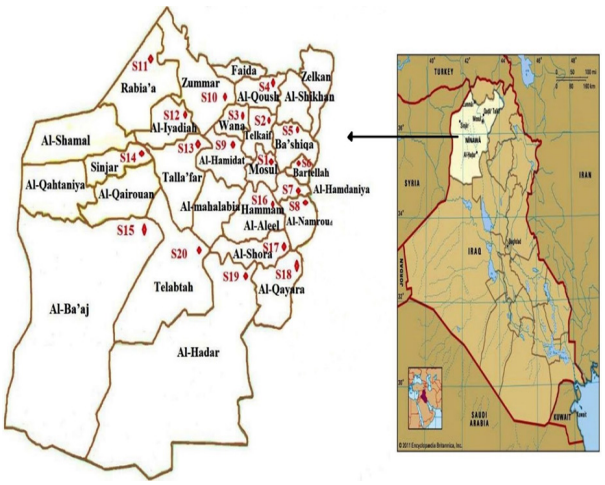

Fig 1. The sitemap of the samples.

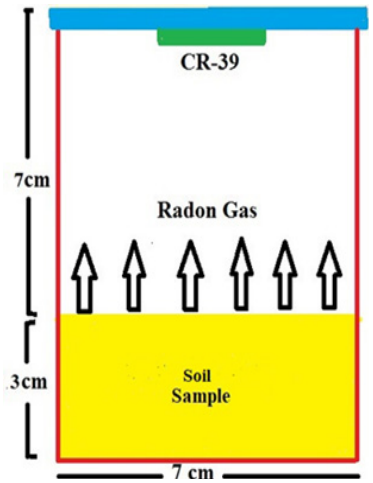

Fig 2. The sealed-can technique (uranium dosimeter).

Since the unit of Bq is equal to decay/s and each decy leaves a track on the detector then 1Bq = 1track/s, then K will be in unit of (m). The Sensitivity K is given traditionally, in track/cm^2 per Bq.d/m^3. To convert K from the definition in equation (3) to traditionally, the units (cm, d) must converted to (m, s), where 1m = 100 cm, 1day = 86400s, then subtiuting the values of m, s in equation (3) produce

$$(m) = (\text{track}.cm^{-2}10^{-4})/(\text{Bq}.\text{d}\ \frac{1}{86400}.m^{-3}).$$

Then, $(m) = 8.64(\text{track}.cm^{-2})/(\text{Bq}.\text{d}\,.m^{-3})$.

Divided by 8.64 to convert to m or m must be multiplied by 8.64 to convert to track.cm^{-2} per Bq.d.m^{-3} or by 0.0864 if K in cm) [14]. K determined using the relation.

$$K = (\frac{1}{4})r(2cos\theta_c - r/R_i) \quad (3)$$

where, the sealed container radius r is 3.5 cm, θ_c is the critical angle of the CR-39 detector equal to 35^o, and R_i is the range of alpha particle in air equal to 4.09 cm (for alpha particle emitted from radon with energy 5.49 MeV) [15-17]. R_i is calculated by the relation.

$$R_i = 0.318\ E_i{}^{3/2} \quad (4)$$

K is then equal to 0.684 cm and has the value (0.0591 Traks.cm^{-2}.day^{-1}/Bq.m^{-3}) after multiplying by 0.0864 [18]. The formula determines the sample's radon concentration Rn [19].

$$C_s = \lambda_{Rn} C_{Rn} HT/L \quad (5)$$

where C_s (Bq.m^{-3}) represents the inside sample's radon concentration, the C_{Rn} (Bq.m^{-3}) represents radon in the air of the sample, λ_{Rn} (0.1814 day^{-1}) of the sample air space The can's air space height, T (sixty days) is the exposure time, and the radon decay constant, H (7 cm). L (3cm) is the thickness of the sample. The activity of the sample's radon (A_{Rn}) was calculated using the formula.

$$A_{Rn} = C_s V \quad (6)$$

where A_{Rn} represents the sample radon activity. The scan radius is r, and the sample's volume is (V = πr^2 L) = 115.4X10^{-6}m^3 [20]. From the radon activity and the number of radon atoms N_{Rn}, the uranium concentration is obtained using the following formula [21].

$$A_{Rn} = \lambda_{Rn}\, N_{Rn} \quad (7)$$

The uranium atoms number in the sample (N_U) is calculated using the equation of secular equilibrium, which states that uranium activity is equal to radon activity.

$$\lambda_U N_U = \lambda_{Rn} N_{Rn} \quad (8)$$

Where λ_U (4.883X10^{-18} sec^{-1}) is the decay constant of uranium and the equation determines the weight of uranium inside the sample [22].

$$W_U = N_U\ At_U\ /N_{avo.} \quad (9)$$

The Avogadro number is Navo. (6.02X10^{23} atom/mol), and the mass number of uranium is represented by At_U. The concentration of uranium is calculated from relation [23].

$$C_U = W_U/W_s \quad (10)$$

where, Ws (50 grams) is the sample mass and C_U (ppm) is the uranium concentration [24].

3. RESULTS AND DISCUSSION

The results obtained from the present study are presented in Table 1. It was discovered that the range of uranium concentrations was (0.129 - 0.281) ppm, and the mean value was 0.182 ppm as displayed in Figure 3. The estimated radon concentration values in soil samples fall within the range of (27.221 - 59.407) Bq.m^{-3}. The uranium content and soil location determine the uranium concentration values in the samples, which vary from one sample to the next. The local geology of the area, along with mineralization, geophysical, and climatological factors, determines the amount of radon gas in the soil and the rate at which it is exhaled. Mountainous areas and near hills have higher concentration values than areas near the river because river flow may reduce concentrations.

Sample S15 Al-Ba'aj had the lowest reported Uranium concentration (0.129 ppm), which is an open soil area without stones far from the river water. While sample S11 Rabia'a had the highest value (0.281 ppm), this location is a large agricultural area

Table 1. Soil sample findings related to track density, the radon concentration in the sample air, radon concentration in the soil, and uranium concentration.

S. No.	Location	ρ Track / cm^2	C_{Rn} Bq/m^3	C_S Bq/m^3	C_U ppm
S1	Mosul	120	33.898	860.8814	0.160
S2	Telkaif	140	39.719	1008.709	0.188
S3	Wana	131	37.151	943.4912	0.176
S4	Al-Qoush	119	33.727	856.5335	0.160
S5	Ba'shiqa	138	39.034	991.3179	0.185
S6	Bartellah	132	37.322	947.8391	0.177
S7	Al-Hamdaniya	141	40.061	1017.405	0.190
S8	Al-Namroud	128	36.295	921.7518	0.172
S9	Al-Hamidat	198	56.154	1426.106	0.266
S10	Zummar	180	51.018	1295.67	0.242
S11	Rabia'a	210	59.407	1508.716	0.281
S12	Al-Iyadiah	121	34.240	869.5771	0.162
S13	Talla'far	155	43.828	1113.059	0.207
S14	Sinjar	166	46.909	1191.321	0.222
S15	Al-Ba'aj	96	27.221	691.3138	0.129
S16	Hammam Al-Aleel	165	46.704	1186.103	0.221
S17	Al-Shora	108	30.576	776.5324	0.145
S18	Al-Qayara	105	29.720	754.7929	0.141
S19	Al-Hadar	102	28.899	733.9231	0.137
S20	Telabtah	100	28.419	721.749	0.134
	Min	96	27.221	691.3138	0.129
	Max	210	59.407	1508.716	0.281
	Mean	137.5	38.917	989.84	0.182

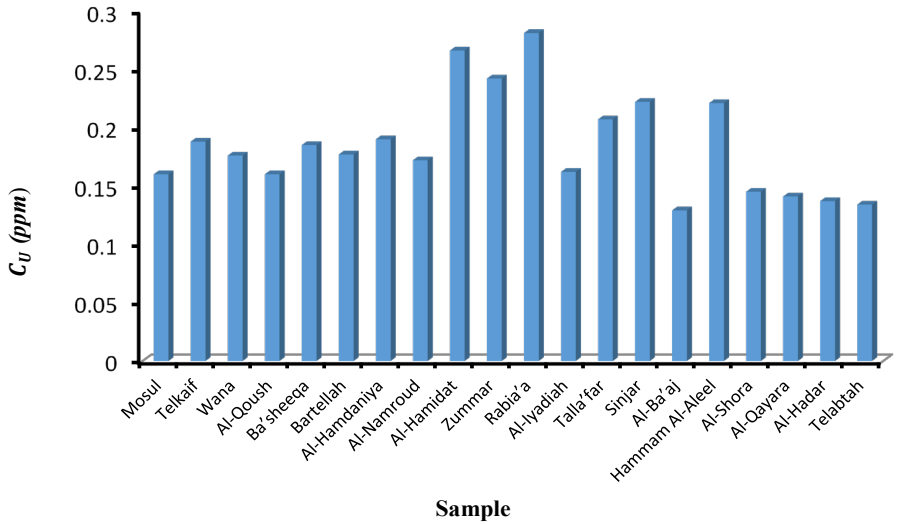

Fig 3. The uranium concentration (ppm) in samples.

Table 2. The compression of results with other measurements in Iraq.

No.	Research	Location	Uranium concentration (ppm)		
			Min	Max	Mean
1.	Present work	Nineveh province -Iraq	0.129	0.281	0.182
2.	[25] 2017	AL-Hamdaniya-Mosul-Iraq	0.313	0.784	0.488
3.	[26] 2015	Sulaimani - Iraq	1.253	18.225	6.029
4.	[27] 2014	Al-Najaf - Iraq	0.0935	0.1843	
5.	[28] 2013	Jalawla'a city-Diyala-Iraq	0.719	1.280	
6.	[29] 2022	Southern Basrah governorate	0.65	2.67	1.382
7.	[30] 2023	Um Qasr district, Iraq	0.6	2.2	1.3

in which organic and chemical fertilizers are widely used. These fertilizers may contain a percentage of radioactive materials, although the percentage is small, but it may contribute to increasing uranium concentrations in this area. The average uranium concentration was 0.182 ppm which is lower than the global average of 11.7 ppm. The compression with recent measurements in Iraq is displayed in Table 2.

Table 2 indicates that the obtained values fall within a certain range of values published for different regions of Iraq. It is far lower than the Sulaimani region, Um Qasr district, and the southern Basrah governorate. Higher than the Al-Najaf area, it lies in the middle of the other measurements in the AL-Hamdaniya region of Mosul and regions of Jalawla'a city-Diyala. The origin of soil types, geochemical makeup, and reported concentrations on dry soil samples all point to the possibility that radioactively rich sandstone is the source of the elevated recorded radionuclide values in the soil sample from that particular area. Therefore, it was concluded that no harmful effects from the radiation and that the population of the research zone is safe from radioactive threats and health concerns coming from the concentrations of uranium in the soil.

4. CONCLUSIONS

The majority of the investigation's uranium-specific activity result values showed that soil samples had less uranium than the average amount found worldwide. Sample S15 Al-Ba'aj had the lowest reported Uranium concentration, which is an open soil area without stones far from the river water. While sample S11 Rabia'a had the highest value, this location is a large agricultural area in which organic and chemical fertilizers are widely used. These fertilizers may contain a percentage of radioactive materials, although the percentage is small, but it may contribute to increasing uranium concentrations in this area. It was discovered that the uranium content was below both the UNSCEAR-recommended global average of 2.8 ppm and the maximum permissible level of 11.7 ppm. Therefore, it was concluded that no harmful effects from radiation and that the population of the research zone is safe from radioactive threats and health concerns coming from the concentrations of uranium from the soil.

5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

6. REFERENCES

1. S. Rahman and M. Faheem. Natural radioactivity measurements in Pakistan an overview. *Journal of Radiological Protection* 28(4): 443-52 (2008).
2. K. Kapanadze, A. Magalashvili, and P. Imnadze. Distribution of natural radionuclides in the soils and assessment of radiation hazards in the Khrami Late Variscan crystal massif (Georgia). *Heliyon* 5(3): e01377 (2019).
3. P. Egidi. Introduction to Naturally Occurring Radioactive Material (01 August 1997, No. CONF-970795-1). *Oak Ridge National Lab. Grand Junction CO. United States* (1997).
4. G. Graetz. Energy for whom? Uranium mining, Indigenous people, and navigating risk and rights in Australia. *Energy Research and Social Science* 8: 113–126 (2015).
5. P. Todorov and E. Ilieva. Contamination with

uranium from natural and anthropological sources. *Romanian Journal of Physics* 50(9-10): 25–30 (2005).
6. A. Tanner. *Radon Migration in the Ground*: a supplementary review. In: Natural radiation environment III: proceedings of a symposium held at Houston, Texas, (DOE Symposium Series 51) 1: 5-55 (1978).
7. M.H. Kheder. Radium and Uranium Concentrations in Some Fruits and Vegetables Cultivated in Nineveh Governorate, Iraq. *Iraqi Journal of Applied Physics* 19(3B): 15-19 (2023).
8. S. Sahoo. Measurement of uranium and its isotopes at trace levels in environmental samples using mass spectrometry. *Indian Journal of Physics* 83: 787–797 (2009).
9. B. Saied, R. Al-Khafaji, and A. Al-Bayati. Measurement of Uranium Concentration in the Soil Samples by Using Solid State Nuclear Track Detectors (SSNTDs). *International Journal of Scientific Research and Technology* 2(4): 130–135 (2016).
10. UNSCEAR. *United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation*. vol. 2. United Nations New York (2000).
11. R.L. Fleischer, P.B. Price, and R.M. Walker. Nuclear Tracks in Solids: Principles and Applications. *University of California Press* (1975).
12. M. Kheder. Measurement of radon concentration using SSNTD in Bartella region. *Al-Mustansiriyah Journal of Science* 29: 110–116 (2019).
13. N. Ahmad, M. Jaafar, S. Khan, T. Nasir, S. Ahmad, and M. Rahim. Measurement of radon exhalation rate, radium activity and annual effective dose from bricks and cement samples collected from Dera Ismail Khan. *American Journal of Applied Sciences* 11: 240 (2014).
14. D. Nikezic, K. Yu, and J. Stajic. Computer program for the sensitivity calculation of a CR-39 detector in a diffusion chamber for radon measurements. *Review of Scientific Instruments* 85: 22102 (2014).
15. M. Kheder, H. Azeez, and F. Al-Jomaily. Alpha Emitters Radioactivity Concentrations in Some Cosmetics Used in Iraq Using LR-115 Detector. *EUREKA: Physics and Engineering* 2: 65–70 (2020).
16. M. Mansy, M. Sharaf, H. Eissa, S. El-Kamees, and M. Abo-Elmagd. Theoretical calculation of SSNTD response for radon measurements and optimum diffusion chambers dimensions. *Radiation Measurements* 41: 222–228 (2006).
17. A.Kh. Thannon, M.H. Kheder, Y.Y. Kassim, and H.N. Azeez. Environmental and Radioactive Contamination in the Village of Kabarli in the Nineveh Plain Region in Iraq. *Iraqi Journal of Applied Physics* 20(3): 561-564 (2024).
18. M. Kheder, L. Najam, R. Mahmood, and F. Majeed. Radioactivity concentrations in barley and wheat crops in Nineveh plain region in Iraq. *International Journal of Nuclear Energy Science and Technology* 14(1): 50–60 (2020).
19. G. Somogyi, A. Hafez, I. Hunyadi, and M. Toth-Szilagyi. Measurement of exhalation and diffusion parameters of radon in solids by plastic track detectors. *International Journal of Radiation Applications and Instrumentation. Part D. Nuclear Tracks and Radiation Measurements* 12(1-6): 701–704 (1986).
20. M. Kheder, A. Ahmad, H. Azeez, and I. Mustafa. Radium and Uranium Concentrations of Powder Juice in the Iraq Markets Using CR-39 Detector. *Journal of University of Babylon for Pure and Applied Sciences* 27 (6): 341–349 (2019).
21. M. L'Annunziata (Ed.). 2nd edition. Radioactivity: introduction and history, from the quantum to quarks. *Elsevier* (2016).
22. E. Podgorsak (Ed.). Basic Radiation Physics. Radiation Oncology Physics: A Handbook for Teachers and Students. *IAEA, Vienna Austria* (2005).
23. M. Kheder, L. Najam, and H. Azeez. Long-lived alpha emitters concentrations in the spices consumed in Iraq using CR-39 detector. *Journal of University of Babylon for Pure and Applied Sciences* 28(1): 274–283 (2020).
24. M. Kheder, A. Ahmad, H. Azeez, M. Slewa, B. Badr, and S. Sleeman. Radon and uranium concentration in ground water of nineveh plain region in Iraq. *Journal of Physics: Conference Series* 1234: 012033 (2019).
25. M. Kheder, H. Azeez, M. Slewa, and T. Zaker. Determination of Uranium Contents in Soil Samples in Al-Hamdaniya Region Using Solid State Nuclear Track Detector CR-39. *Al-Mustansiriyah Journal of Science* 30(1): 199–204 (2019).
26. K. Abdullah, S. Muhammed, and A. Hussein. Assessment of Rn and U concentrations in the soil of Qadafery, Kalar and Zarayan located in Sulaimani governorate of Kurdistan region-Iraq. *American Journal of Environmental Protection* 4(1): 40–44 (2015).
27. A. Abojassim. Uranium concentrations measurement for groundwater and soil samples in Al-Najaf/Iraq.

IOSR Journal of Applied Chemistry 6: 61–65 (2014).
28. A. Mohammad, I. Ahmed, and Y. Ahmed. Measurement of Uranium Concentration in Some Soil Samples in Jalawla'a City Using CR-39 Detector. *Al-Nahrain Journal of Science* 16(1): 112–116 (2013).
29. T.M. Salman and M.A. Algrifi. Measurement of Uranium Concentration in Basrah Soils Using the CR-39 Detector. *Biomedicine and Chemical Sciences* 1(3): 164-167 (2022).
30. M.A. Algrifi and T.M. Salman. Measuring uranium concentration in Um Qasr district, southern Iraq, in two different ways. *Applied Radiation and Isotopes* 192: 110595 (2023).