Research Article

Determination of Uranium Contents in Soil Samples in Al-Hamdaniya Region Using Solid State Nuclear Track Detector CR-39

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Abstract

Uranium is a common radioactive element in Earth's crust (soil, rock), so it is important there quantity to be under control. The concentration of uranium in soil varies widely, depending on the geological location its concentration in the surface soil vary from 0.1 mg.Kg^{-1} (ppm) to 20 mg.Kg^{-1} (ppm) with a world average of 2.8 ppm and the permissible limit 11.7 ppm. The uranium concentration, radon activity, radon concentration, in twenty soil samples collected from AL-Hamdaniya region, east of Mosul City north of Iraq, were measured using can technique based on Solid State Nuclear Track Detectors (SSNTDs) CR-39. The estimated values for the uranium activity which equal to radon activity at secular equilibrium were found to be (581.11-1453.5) mBq with mean value 905.89 mBq, the uranium concentration are between (0.313-0.784) ppm with mean value of 0.488 ppm. All values of the samples under the test are below the allowed limit and worldwide average value.

Keywords: Uranium Concentration, Radon Activity, AL-Hamdaniya Region, CR-39.

الخلاصة

تم قياس تراكيز اليورانيوم وفعالية الرادون لعشرون عينة تراب جمعت من منطقة الحمدانية باستخدام كاشف الاثر CR-39 وكانت النتائج المحصلة لفعالية اليورانيوم التي هي في حالة توازن مع فعالية الرادون تقع بالمدى (581.11-1453.5) mBq وبمعدل 905.89 mBq بينما كانت تراكيز اليورانيوم بالمدى ppm (0.313-0.784) وبمعدل 0.488 ppm وكانت جميع القيم اقل من الحدود المسموحة 11.7 ppm واقل من 2.8 ppm التي هي المعدل العالمي.

Introduction

The radiation that we exposed to is referred to the natural background radiation; it has been a part of human environment. Its main components are cosmic and cosmogenic radiation in rocks and soil, and natural radioactive substances [1]. One of the main determinations of the natural background radiation is the soil radionuclide activity concentration [2].

The soil is naturally radioactive, because of the mineral content. The natural radioactivity may vary considerably from one type of soil to another. Radionuclides are found in the environment and soil, as naturally occurring elements and as product of nuclear technologies, one of these radionuclides is uranium [3].

Uranium like many other minerals is naturally occurring element that has always been present, since the formation of the earth. It has been deposited on land by volcanic action, dissolved by rainfall. All isotopes of uranium are radioactive, so it is very important there quantity to be under control [4]. The abundance and half-life of a uranium isotope determine its contribution to the radioactivity of natural uranium. It decays by emitting alpha particles, becoming nonradioactive lead. Each new radionuclide along the decay chain is called a progeny (or decay product), it is contributed about seven times more to the total radioactivity of soil than that of the uranium itself. Uranium is the proximate source of radium and radon in the soil and rocks. Radon a progeny of uranium, is one of the largest contributors to our background radiation. Radon is a gas, so can escape from the ground. We are exposed to various concentrations of radon depending on a number of factors, including the amount of uranium in the soil [5].

Uranium accumulated in humans may have a dual effect due to its chemical and radioactive properties. High intake of uranium and its decay products may lead to harmful effects in human beings [6]. An exposure of about 0.1 $mg.Kg^{-1}$ of body weight of soluble natural uranium results in transient chemical damage to the kidneys [7]. The concentration of uranium in soil varies widely. Depending on the geological location, its concentration in the surface soil vary from 0.1 $mg.Kg^{-1}$ to 20 $mg.Kg^{-1}$ with a world average of 2.8 mg. Kg^{-1}(specific activity 35 Bq/Kg) [8], and the allowed limit 11.7 ppm [10] .

CR-39 (The plastic SSNTD) detector was used to find the concentration of uranium in the soil. Because of the advantage of its high sensitivity, efficiency, ease and accuracy in determining the emitting elements of the alpha particles even if the concentration is very small. These tracks observed by microscope after enlargement by etching process [12].

The aim of this research was to determine uranium concentration in twenty soil samples from AL-Hamdaniya region. The measurement of uranium concentration is necessary to investigate the concentration in causing various diseases, especially cancer.

Materials and Methodology

Uranium dosimeter techniques were used, the measurements were made with solid-state nuclear track detector (SSNTD) technique as shown in Figure 1.

Each cup container is 7cm heights and 6.5cm in diameter and contains (1 × 1) cm square of CR-39 nuclear track detector fixed with double-sided adhesive tape to the bottom of cover of the cup. The CR-39 detector was capable of detecting alpha particles of all energies emitted from radon and its daughters. Some of alpha particles reach the detector and leave tracks. The number of tracks is proportional to the average radon concentration.

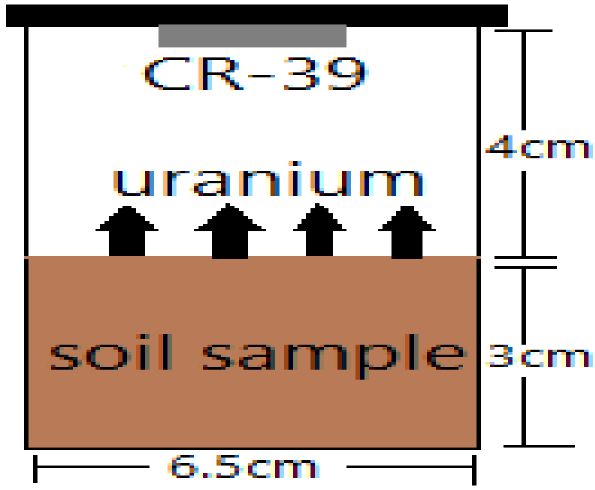

Figure 1: A schematic diagram of the sealed-can technique in soil sample.

Twenty soil samples were collected from various locations of AL-Hamdaniya region. These samples milled, dried, crushed, sieved by 2-mm mesh, 150 gm of each sample was placed inside a plastic cylindrical container (uranium dosimeter) facing a CR-39 track detector. The distance between the sample surface to the detector is 4 cm and the sample height is 3cm, then closed for a period of 90 days (from 10 March 2017 to 8 June 2017).

After 90 days the detectors are removed and etched by NaOH at normality 6.25 N and heat 70 ºC in water bath to reveal the tracks. The detectors were washed and dried, tracks were counted using a microscope at a magnification of 400x.

The track densities were measured using the following equation [14]:

$$\rho = \frac{\sum_i N_i}{nA} \quad (1)$$

Where: A is the area of the field of view , N_i is the total number of tracks and n is the total number of fields of views .

The radon concentration in air space C_{Rn}(Bq/m^3) is related to the track density ρ(in track/cm^2) and the exposure time T(in day) by the formula [15] :

$$\rho = K C_{Rn} T \quad (2)$$

Where K is the sensitivity or calibration factor of CR-39 its value (2.758 × 10^{-2} Traks. cm^{-2}. day^{-1} / Bq.m^{-3}) given by ref. [16].
Radon Rn concentration in the samples calculated by using the relation [17]

$$C_s = \lambda_{Rn}\, C_{Rn}\, H\, T/L \tag{3}$$

Where C_s Radon concentration in the samples (Bq/m^3), C_{Rn} Radon concentration in air space (Bq/m^3), λ_{Rn} decay constant for radon (0.1814 day^{-1}), H height of air space in the can (4 cm), T exposure time (90 day), L thickness of the sample in the can (3cm).
The activity of radon in the sample (A_{Rn}) could be determined through relation [19]:

$$A_{Rn} = C_s\, V \tag{4}$$

Where A_{Rn} activity of radon, V the volume of sample ($V = \pi r^2 L$) = 99.5 X 10^{-6} m^3, r is can radius.
Uranium concentration can be determined through the activity of radon by the number of atoms of radon N_{Rn} using the relation [20]:

$$A_{Rn} = \lambda_{Rn}\, N_{Rn} \tag{5}$$

And by using the equation of secular equilibrium (activity of uranium equal activity of radon) one can determine the number of atoms of uranium N_U in the samples [21]:

$$\lambda_U\, N_U = \lambda_{Rn}\, N_{Rn} \tag{6}$$

Where λ_U is decay constant of uranium (4.883 X 10^{-18} sec^{-1}), then the weight of uranium in the samples could be calculated from [23]:

$$W_U = N_U\, At_U\, / N_{avo.} \tag{7}$$

Where At_U uranium mass number ^{238}U, $N_{avo.}$ Avogadro number (6.02 X 10^{23} atom / mol)
Uranium concentration then can be calculated by:

$$C_U = W_U\, / W_s \tag{8}$$

Where C_U uranium concentration in (ppm), W_s mass of samples which is used in gram (150 gm).

Results and Discussion

The results of the track density, radon concentration, and uranium activity, uranium weight in sample, uranium concentration, for twenty soil samples are presented in Table 1.
The calculated values for radon concentration in soil samples are in the range (5840.3-14608.5) Bq/m^3 with mean value of 9104.52 Bq/m^3, the radon activity were found vary between (581.11-1453.5) mBq with mean value 905.89 mBq which equal to specific activity of 6.04 Bq/Kg by dividing activity on sample mass in Kg (0.150 Kg), the uranium concentration (0.313-0.784) ppm with mean 0.488 ppm. Where the min values found in the sample no.21 Al-Hamdaniya apartments and max values in sample no.2 Karamlis apartments, All values of the samples under the test are below of allowed limit 11.7 ppm, and world average value 2.8 ppm. In (Table 2), compression with some other measurements in Iraq, show that the estimated results are less than these measurements, the area under study is safe for life from uranium concentrations.
Figure 2 the variation of the values of the uranium concentration in the samples, its vary from one sample to another due to uranium content in sample.
In Figure 3 a good positive correlation (1.00) has been obtained between the uranium concentration and the radon concentration in soil samples. It is indicate that the radon concentration will increase as the content of uranium increased.

Table 1: Results of the track density, radon concentration, and uranium activity, uranium weight in sample, uranium concentration in soil samples.

S.	Location	ρ Track/cm^2	C_S Bq/m^3	$AU=A_{Ra}$ mBq	WU X10^{-6} gm	C_U ppm
1.	Hamdaniya aprtments	666	5840.3	581.11	47.04	0.313
2.	Sanhareeb Q.	760	6663.1	662.97	53.67	0.357
3.	Gazino Onil	893	7829.9	779.07	63.07	0.420
4.	ALShuhadaa Q.	840	7366.2	732.93	59.34	0.395
5.	Akad Q	933	8180.4	813.95	65.90	0.439
6.	ALMuaalamin Q.	1466	12856.1	1279.2	103.56	0.690
7.	Sumer Q.	1333	11689.4	1163.1	94.16	0.627
8.	Ashor Q.	1213	10635.8	1058.2	85.67	0.571
9.	Musa Q.	866	7592.6	755.46	61.16	0.407
10.	Simenir	960	8417.6	837.55	67.81	0.452
11.	Nvertaya	906	7943.1	790.33	63.98	0.426
12.	Kalih Q.	826	7242.2	720.60	58.34	0.389
13.	Industrial area	800	7013.6	697.85	56.50	0.376
14.	AL-Baath Q.	1200	10522.6	1047	84.76	0.565
15.	AL-Wahda Q.	946.6	8300.1	825.86	66.86	0.445
16.	Municipal Nursery	1133	9934.9	988.52	80.03	0.533
17.	Saint Barbara	1000	8768.1	872.42	70.63	0.470
18.	Eastern Karamlis	1266	11101.6	1104.6	89.43	0.596
19.	Karamlis Apartments	1666	14608.5	1453.5	117.68	0.784
20.	Garden of Karamlis	1093	9584.4	953.64	77.21	0.514
	Min	**666**	**5840.3**	**581.11**	**47.04**	**0.313**
	Max	**1666**	**14608.5**	**1453.5**	**117.68**	**0.784**
	Mean	**1038**	**9104.52**	**905.89**	**73.34**	**0.488**

Table 2: Compression with recent measurements in Iraq

N	Researcher	Location	Uranium concentration (*ppm*)		
			Min	Max	Mean
1.	Present work	AL-Hamdaniya-Mosul-Iraq	0.313	0.784	0.488
2.	2014 ref. [24]	Al-Najaf - Iraq	0.093558	0.184325	--------
3.	2013 ref. [25]	Jalawla'a city-Diyala-Iraq	0.719	1.280	--------
4.	2016 ref. [11]	Tuwaitha - Baghdad - Iraq	1.07	4.20	2.40
5.	2015 ref. [26]	Sulaimani - Iraq	1.253	18.225	6.029

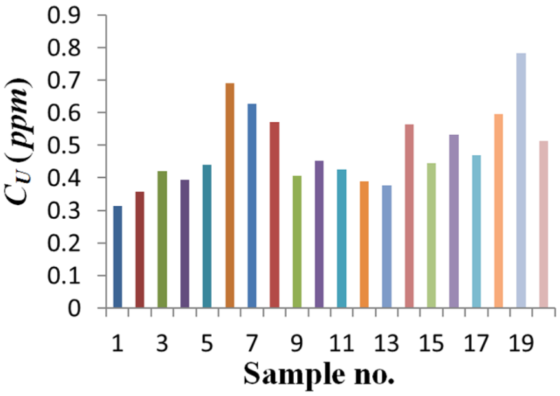

Figure 2: Uranium concentration (*ppm*) in samples.

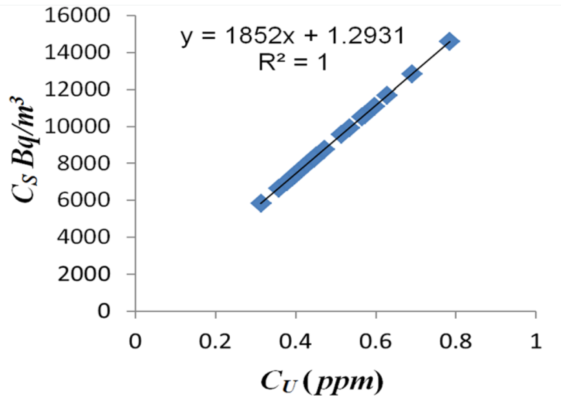

Figure 3: relation between radon concentration and Uranium concentration.

Conclusions

The results of this investigation showed low presence of uranium in soil samples in AL-Hamdaniya region. A correlation coefficient of 1.00 between the uranium concentration and radon concentration in soil sample obtained it is evident that as the content of uranium increased, the radon concentration as well as increase. The obtained values of uranium concentration were found to be less than the maximum permissible limit 11.7 ppm and worldwide average value 2.8 ppm as the recommended by UNSCEAR. Hence the area under investigation is safe as for as health hazards and radiological risks due to uranium concentration in the soil.

References

[1] Bochicchio F., McLaughling J. and Piermattei S., "Radon in indoor air", (European Collaborative Action, Report, No. 15, P. 50, (1995).

[2] Taskin H., Pinar A., Karavus M., and Karahan G., "Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli Turkey", Journal of environmental radioactivity, Vol. 100(1), (49-53), (2009).

[3] White R. E.,"Principles and practice of soil science: the soil as a natural resource". (John Wiley & Sons), (2013).

[4] Steven H. Brown, "Uranium : A Citizen's Guide to Uranium" Health Physics Society Specialists in Radiation Safety, (2011)

[5] Todorov P., and Ilieva E. N., "Contamination with uranium from natural and anthropological sources", Rom. Journ. Phys., Vol.51(1-2), (27-34), (2006) .

[6] Dyck W.,"Application of Hydro Geochemistry to the Search of Uranium", Economic Geology Reports, 31, 489- 510, (1979) .

[7] Tanner A.B.,"Radon Migration in the Ground: A Supplementary Review. In: Gesell, T.F. and Lowder, W.M., Eds., The Natural Radiation Environment III", National Technical Information Services, National Technical Information Service, Springfield , 5-56, (1980) .

[8] Sahoo S. K., "Measurement of uranium and its isotopes at trace levels in environmental samples using mass spectrometry", Indian J. Phys., 83 (6) 787-797, (2009) .

[9] UNSCEAR"Sources and effects of Ionizing Radiation,Report to the General Assembly, (NewYork : United Nations), Vol. I., (2000) .

[10] UNSCEAR, United Nations Scientific Committee on the effect of Atomic Radiation, "Sources, Effect, and Risks of Ionizing Radiation", (Report to the general Assembly with Scientific Annexes, United Nation). (1993).

[11] Bashair M. Saied, Raad M. Al-Khafaji, and Auday T. Al-Bayati, "Measurement of Uranium Concentration in the Soil Samples by Using Solid State Nuclear Track Detectors (SSNTDs)" IJSRST: Science and Technology, [(2)4: 130-135] , (2016) .

[12] Fleischer R. L., Price P. B. and Walker R.M.,"Nuclear Tracks in Solids, Principles and Applications. (Berkeley, USA, University of California Press), (1975) .

[13] Misdaq M. A. and Ouabi H.,"238U and 232Th concentrations in various potable waters in Morocco", J. of Rad. Analy. Nucl. Chem., Vol. 270(3), (543-553), (2006).

[14] Nisar Ahmad, Mohamad Suhaimi Jaafar, Sohail Aziz Khan, Tabassum Nasir, Sajjad Ahmad and Muhammad Rahim," Measurment of Radon Exhalation Rate , Radium Activity and Annual Effective Dose from Bricks and Cement Samples Collected from Dera Ismail Khan", American Journal of Applied Scince, 11(2) p. 240-247, (2014) .

[15] Hamza V. Z., and Mohankumar M. N.,"Cytogentic Damage in Human Blood Lymphocytes Exposed in Vitro to Radon" Mutation Research, 661, p.1-9, (2009) .

[16] Marcia Pires de Campos and Elaine Wirney Martins," Calibration of the Solid State Nuclear Track Detector CR-39 for Radon Measurments" , Associacao Brasileira De Energia Nuclear –ABEN , ISBN: 978-85-99141-02-1,(2007) .

[17] Somogi G., Hafiz A., Hunyadi I. and Toth-Szilagyi M., "Measurement of Exhalation and Diffusion Parameters of Radon in Solids by Plastic Track Detectors" ,Nucl. Track Radit. Meas., 12(1-6), pp 701-704, (1986).

[18] AL-Bataina B. A., Ismail A. M., Kullab and et.al," Radon Measurement in different type of nature waters in Jorden" , Radiation Measurement, 28(1-6); 591-594, (1997) .

[19] Ahmad M., "Employment SSNTD (CR-39) to Detect Radioactive Pollution of DU in a Particular Region from Salahadeen Governorate" Proceeding in Ist Scientific Conference for College of Science University of Tikrit. Iraq, pp295, (2011) .

[20] Michael F. Annunziata, Radioactivity Introduction and History", 1st edition USA, (2007).

[21] Podgorsak E.B., "Basic Radiation Physic", Radiation oncology physics, IAEA in Austria, Ch.1, pp1, (2005).

[22] Sroor A., El-Bahi S.M., Ahmed F., and Abdel-Haleem A.S.," Natural Radioactivity and Radon

Exhalation rate of Soil in Southern Egypt" Applied Radiation and Isotopes, vol.55, pp873, (2001) .

[23] Samuel S.M., " Introductory Nuclear Physic", 2nd Edition, University of Toronto (2004) .

[24] Abojassim Ali A., "Uranium Concentrations measurement for Ground Water and Soil Samples in Al-Najaf/Iraq " , IOSR Journal of Applied Chemistry (IOSR-JAC), Volume 6, Issue 5, PP 61-65, (2014).

[25] Ali M. Mohammad, Israa k. Ahmed and Yasir S. Ahmed," Measurement of Uranium Concentration in Some Soil Samples in Jalawla'a City Using CR-39 Detector", Journal of Al-Nahrain University, Vol.16 (1), pp.112-116, (2013) .

[26] Kamal O. Abdullah, Salar Z. Muhammed, and Adil M. 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) .