Measurement of radon and uranium concentration in soil samples from Babylon cement plant using nuclear track detector CR-39

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Abstract

In this study, concentrations of radon and uranium were measured for twenty six samples of soil. The radon concentrations in soil samples measured by registrant alpha-emitting radon (^{222}Rn) by using *CR-39* track detector. The uranium concentrations in soil samples measured by using registrar fission fragments tracks in *CR-39* track detector that caused by the bombardment of *U* with thermal neutrons from ^{241} *Am-Be* neutron source that has flux of $5 \times 10^3 n\ cm^{-2}\ s^{-1}$.

The concentrations values were calculated by a comparison with standard samples The results show that the radon concentrations are between (91.931-30.645Bq/m^3).

The results show that also the uranium concentrations are in soil samples under 0.051-0.0079ppm.

Key words

Radon concentration, Uranium concentration soil, plant nuclear track detector CR-39.

Article info.

Received: Apr. 2014
Accepted: Jun. 2014
Published: Sep. 2014

قياس تركيز الرادون واليورانيوم في بعض نماذج التربة من معمل سمنت بابل باستخدام كاشف الأثر النووي CR-39

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الخلاصة

تم في هذه البحث قياس تراكيز غاز الرادون واليورانيوم لسته وعشرون عينة ترابية من معمل سمنت بابل الواقع الى الجنوب من مدينه بغداد وتم ايجاد تراكيز الرادون Rn^{222} عن طريق تسجيلِ اثار بواعث ألفا المنبعثة من غاز الرادون (^{222}Rn) في كاشِف الأثر النووي (CR-39).

و تم تحديد تراكيز اليورانيوم في عينات الترب عن طريق تسجيل أثار شظايا الانشطار في كاشف الأثر النووي(*CR-39*) الناتجة من قصف نوى اليورانيوم بالنيوترونات الحرارية من المصدر النيوتروني (^{241}*Am-Be*) بفيض نيوتروني حراري (5×10^3 n cm^{-2} s^{-1}).

تم تحديد التراكيز بالحسابات المعتمدة على المقارنة مع العينات القياسية، ومن خلال النتائج المستحصلة وجدنا ان تراكيز الرادون تتروح مابين (91.931-30.645Bq/m^3) وان تراكيز اليورانيوم تتروح مابين (0.051-0.0079ppm).

Introduction

Radon (^{222}Rn) is a radioactive gas with a half-life 3.823d that is an element of the periodic table and falls within the noble group elements (Helium, Neon and Xenon, etc.). It is difficult to detect radon because it's a colorless and odorless gas. Its atomic number is 86, boiling point -61.8ºC, freezing point -71.0 ºC and density 9.73 Kg.m^{-3}, and

it is produced by the decay of the natural radioactive uranium series, which starts with uranium (^{238}U) [1].

Uranium is a very widely distributed element in the earth's crust, is presented naturally everywhere in soil, sand and rock in various concentration from one place to another.

Radon can be considered to be one of the most dangerous radioactive elements in the environment [2]. Its character as a noble gas allows it to spread through the atmosphere. The greatest fraction of natural radiation exposure in humans results from inhalation indoor and work places of the decay products of radon [3].

Radon gas can diffuse or be transported to some distance through fissures in the rock structure and find its way into the soil and surrounding material. Therefore, radon measurement is the most promising method for detecting uranium deposits.

A can technique which used in this study based on the registration of alpha tracks from ^{222}Rn on alpha sensitive track detector that was developed for uranium or radon exploration. The detector is exposed to the soil gas to know length of time. The ^{222}Rn alpha tracks are registered on the detector. The alpha track density gives a measure of ^{222}Rn concentration in the soil. As it is a very simple technique, it can be implemented easily for field studies, since they do not require electronic system [4].

Uranium is a radioactive and chemical element, represents by (U) symbol, and it is a heavy metal with a very high density (18.95 g /cm^3, 1.7 times higher than lead's density of 11.35 g /cm^3).

Metallic uranium has a high melting point (1132 ^{o}C) and boiling point (4131 ^{o}C), has a tensile strength similar to most steels and it is chemically very reactive [1]. Natural uranium consists of three isotopes. Their concentrations by mass are ^{238}U 99.276%, ^{235} U 0.718% and ^{234} U 0.0056%[2,3,4].

Recently many attempts have been made to develop the alpha sensitive plastic film (ASPF) family of the solid state nuclear detector (*SSNTDs*) for this purpose[5]. *CR*-39 is one of the solid state nuclear detectors which can response to alpha particle with high efficiency [6]. The authors have successfully applied this method for purpose of uranium exploration.

Nuclear track detector is one of the most popular detectors used to study the nature of damage product by heavily ionization radiation such as alpha particle or fission fragment, the technique of measuring the number of particle by observing their track in certain organic or inorganic materials has been used for the study of phenomena in such diverse fields as geology, astrophysics, and nuclear physics. The technique based on the damage created in a solid along the path of heavily ionizing particle [7] as it is a very simple technique, it can be implemented easily in field of studies, since it does not require electronic system.

Experimental technique

1- Collection of soil samples

Soil Samples were taken from twenty six locations of study factory soil, the samples taken from depth 10-15 cm Then the samples were cleaned, dried in an oven at 70 ^oC for few hours finally they were powdered and sifted by using special sieve 250 μm in diameter [8].

2- Irradiation of the detectors.

For measuring Radon, each sample of soil was taken with 10g weight and placed in plastic can. The dimensions of the can minimize the effect of thoron gas. Pieces of CR-39 track detectors 1× 1 cm area were fixed under the cover of plastic can, which contain the soil samples. The exposure time was 21 days, as shown in Fig. 1 [9].

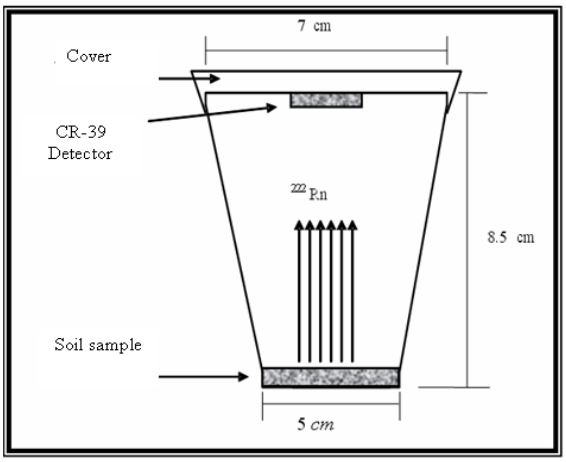


Fig.1: Radon gas (^{222}Rn) estimation by using (CR-39) detector for soil sample.

For measuring uranium concentration, each sample was taken with 0.5*gm* weight of soil samples powder was mixed with 0.1*gm* of methyl cellulose powder used as a binding material. The mixture was pressed into a pellet of 12 *mm* diameter and 1.5 *mm* thickness using a hydraulic machine. The pellets were covered with *CR-39* detector and put in a plate of paraffin wax at a distance of5*cm*from the neutron source *Am-Be*, with flux of thermal neutron 5×10^3 *n* cm^{-2} s^{-1}, as shown in Fig.2.

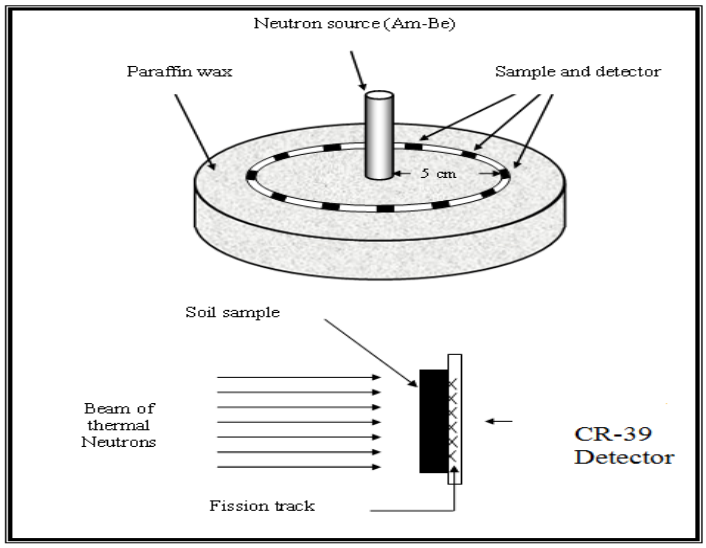


Fig.2: CR-39 detector for measured uranium in soil sample.

3- Chemical etching and microscopic scanning

After the exposure time, the detectors were etched in a 6,25 N aqueous solution of NaOH maintained at 60 ˚C in a water bath for 6hrs, which was the normal employed etching time[8,9]. The detectors were then taken out from the etching, rinsed with distilled water and dried in air. The track density was recorded using an optical microscope with (400x).

The density of the tracks (ρ) in the detectors was calculated according to the following relation:

$$\rho_x = \frac{N_{ave}}{A}$$

where;

ρ: Track density(track /mm^2)

N: Average of total tracks.

A: Area of field view.(mm^2)

4- Radon and uranium concentration

Radon gas ^{222}Rn concentration in the soil samples was measured by making a

comparison between track densities registered on the detectors of the sample and that of the standard geological sample, Fission track technique was used for determination uranium concentration in the soil samples by making a comparison between track densities registered on the detectors of the sample and that of the standard geological sample, from the relation**:**

$$\frac{C_X}{\rho_X} = \frac{C_S}{\rho_S}$$

where

C_S and C_X: specific activity (Bq/m^3) for standard and samples respectively, C_S *and* C_X: Uranium concentration (*ppm*) for standard and sample respectively.

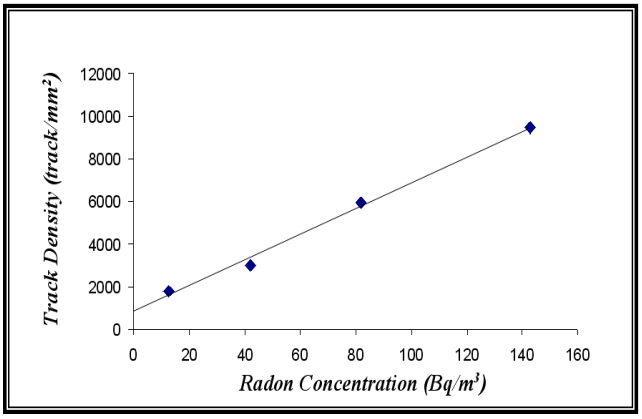
ρ_S and ρ_X: track density (Trtack/mm^2) for standard and sample respectively.

And $C_X = C_S \frac{\rho_X}{\rho_S}$

and $C_X = \frac{\rho_X}{slope}$

$$_{slope} = \frac{c_s}{\rho_S},$$

slope for uranium is=32142.9, slope for radon is=33.3. as show in Fig. 3.



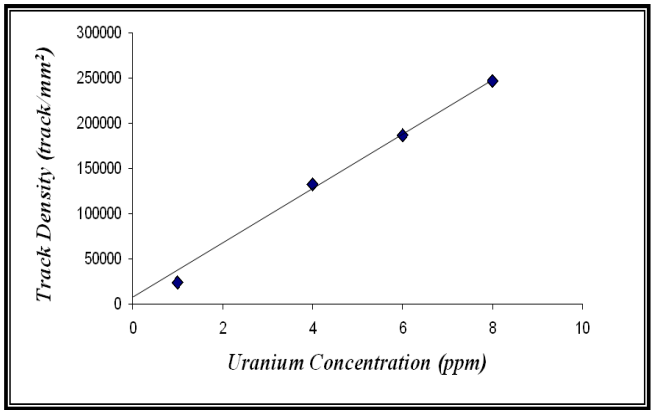


Fig.3: The relation between track density and radon & uranium concentration for standard geological soil samples.[5]

5-Results and conclusions

Table 1 and 2 were showed the radon and uranium concentration in soil samples in the plant. As a conclusion of the study; radon and uranium concentration in this plant is within the normal level[10], which around 11.8ppm and (200-800) Bq/m^3.

From the data in Table1, we found that the maximum value of uranium was 0.051 *ppm* in sample number 15, which is located to the west of the plant, and the minimum value of uranium was 0.0079 *ppm* in sample number 3, which is located to the north- west of the plant. The uranium level in each location was normal within the acceptable values [10].

From the data in Table 2, we found that the maximum value of radon was 91.931 Bq/m^3 in sample number 5, which is located to the south of the plant, and the minimum value of radon was 30.645 Bq/m^3 in sample number 16 Which is located to the west of the plant. The radon level in each location was normal within the acceptable values [10].

In conclusion, we found that the uranium and radon levels in the soil in this field of study within the acceptable values [10].

Table 1: Urainum concentration in soil samples.

No. of samples	Track density Trtack/mm^2	Uranium Concentration ppm
S1	408.2	0.012
S3	255.2	0.0079
S5	816	0.0253
S6	1275.6	0.0396
S7	459.2	0.0142
S8	357.2	0.021
S12	306.2	0.0095
S14	612.3	0.0191
S15	1632.7	0.051
S16	1071.5	0.034
S18	663.3	0.021

Table 2: Radon concentration in soil samples

No. of Sample	Track Density Trtack/mm2	Radon Concentration Bq/m3
S1	2040.9	61.288
S2	1632.7	49.030
S3	1785.8	53.627
S4	2602.1	87.142
S5	3061.3	91.931
S7	2346.94	70.4
S8	1989.8	59.753
S9	1734.7	52.093
S13	1275.6	38.306
S14	2500	75.075
S15	1887.8	56.690
S16	1020.5	30.645
S17	1377.6	41.369
S18	1326.6	39.837

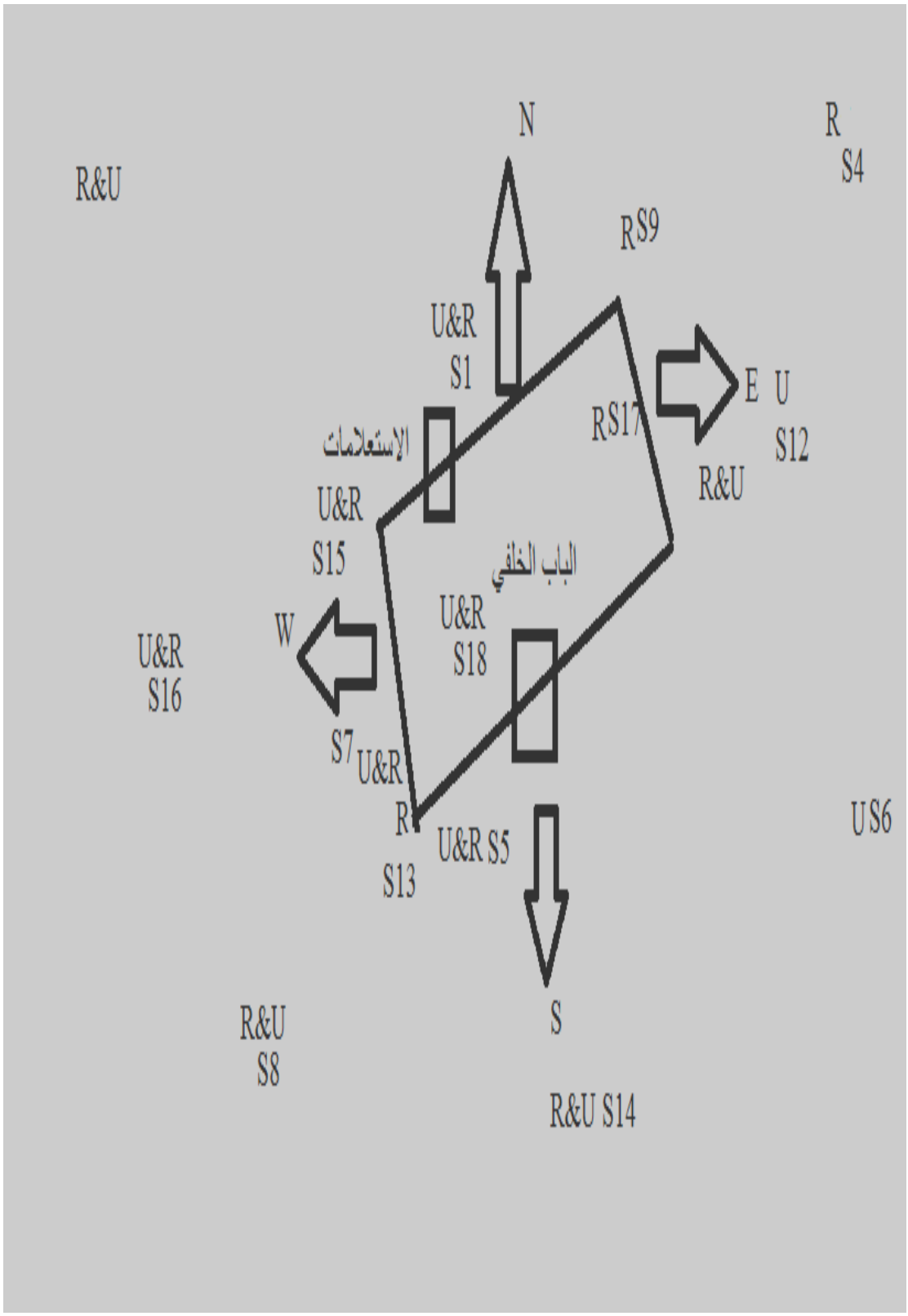


Fig.4: Graphic shows the areas that have been collecting soil samples from cement plant.

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