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Assessment of Rn and U Concentrations in the Soil of Qadafery, Kalar and Zarayan Located in Sulaimani Governorate of Kurdistan Region- Iraq

Kamal O. Abdullah, Salar Z. Muhammed, Adil M. Hussein*

Physic Dep., Faculty of Science and Science Education, University of Sulaimani, Kurdistan region, Iraq

Email address:
kamaloa13@gmail.com (K. O. Abdullah), adiljaff@gmail.com (A. M. Hussein)

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Abstract: The profile of radon (222-Rn) and uranium (238-U) concentrations in15 surface soil samples collected from the three agricultural areas of town Qadafery, Kalar and Zarayan which are located at the east of Sulaimani governorate in Kurdistan Region – Iraq has been determined using solid- state nuclear track detector (CR-39), where Qadafery located in the margin of Suren Mountain, also located in the north of the famous plain of the Middle East region called Sharazoor plain and Zarayan located in the west north of the Sharazoor plain, also its surrounds in another direction by Qaradagh and Barznja mountains. They (Qadafery, Kalar and Zarayan) have been shown that the maximum and minimum values of radon concentration of the air inside the tube were 2242.263±143.152 Bq/m^3 and 154.099±2.579 Bq/m^3, respectively, with average value 741.709±27.234 Bq/m^3 while the maximum and minimum values of uranium concentration are 18.225±12.905 ppm and 1.253±0.233 pmm, respectively, with average value 6.029±2.455 pmm. It appears that higher concentrations of radon and uranium was in soil sample Qadafery_5 and the minimum value was in soil sample Kalar_4 and by comparison with the world values there are some positions in Qadafery and Zarayan with higher level concentrations that is due to the geology information of these regions.

Keywords: Soil, SSNTD, CR-39, Radon, Uranium

1. Introductions

The natural radioactive nuclides like radon is the main source of radiation exposure for human when they are emitted from soil, building materials and natural energy sources which contain ^{238}U traces, and the ^{222}Rn with half-life 3.8 d can be considered to be one of the most dangerous radioactive elements [1,2], when uranium is high in the soil it can cause to ^{222}Rn and its airborne daughter is a significant internal health hazard [3]. Uranium as a heavy metal is a natural constituent of the earth's crust and the presences of it in soil are natural and anthropogenic when the main sources of anthropogenic exist in various industrial sources and agricultural activities such using fertilizer while the result of these activities are causing to soil pollution by these types of heavy metals. The maximum permissible levels of metal concentrations in soil were complying with the idea of preventing toxic exposure of plants, animals and humans [4]. Generally, the distribution of such heavy metals is influenced by kind of main source, climate and relative mobility depending on soil parameters such as mineralogy, texture and category of soil and PH [5].

Noble radon gas (^{222}Rn) originates from radioactive transformation of ^{226}Ra in the ^{238}U decay chain in the earth's crust. Only a fraction of the radon atoms so created is able to emanate from the mineral grains and enter the void space, then radon moves further by correspondence to: A. Gregory diffusion and advection dissolved either in water or in carrier gases. Eventually, it exhales into the atmosphere. The radon emanation depends mainly on ^{226}Ra content and mineral grain size, its transport in the earth governed by geophysical and geochemical parameters, while exhalation is controlled by hydro meteorological conditions [6].

Radon concentrations in soil gas within a few meters of the surface of the ground are clearly important in determining radon rates of entry into pore spaces and subsequently into the atmosphere and it depend on the radium concentration in the bedrock and on the permeability of the soil [7].

In the present study, measurements of radon and uranium concentrations of 15 soil samples collected in three regions, the eastern of Sulaimani governorate, were carried out using Solid State Nuclear Track Detector (SSNTD) technique, in order to assess whether the soil and the general public is at any risk due to this exposure to excessive levels of radon because these regions were used as a farm mostly for agriculture in this area. The results of the present study shall help in determining the positions which have the highest activity of the natural radiation background (Uranium) directly or indirectly affects the human health. The results have been compared to the limits of worldly values.

2. Experimental Method

2.1. Sampling

Fifteen samples were collected from surface soil (until depth 20cm) at each agriculture farm in the studied area in Sulaimani (Kurdistan Region-Iraq). The places Zarayan and Qadafary were situated at the east of Sulaimani, their are geographical coordinates are $35^{o}\ 31^{l}\ 88^{ll}$ North, $45^{o}\ 67^{l}\ 77^{ll}$ East and $35^{o}\ 33^{l}\ 39^{ll}$ North, $45^{o}\ 94^{l}\ 03^{ll}$ East, respectively, but Kalar was situated at the South of Sulaimani with geographical coordinates of 34° 37' 33" North, 45° 18' 31" East, as shown from the map of the studied area in Fig.(1).

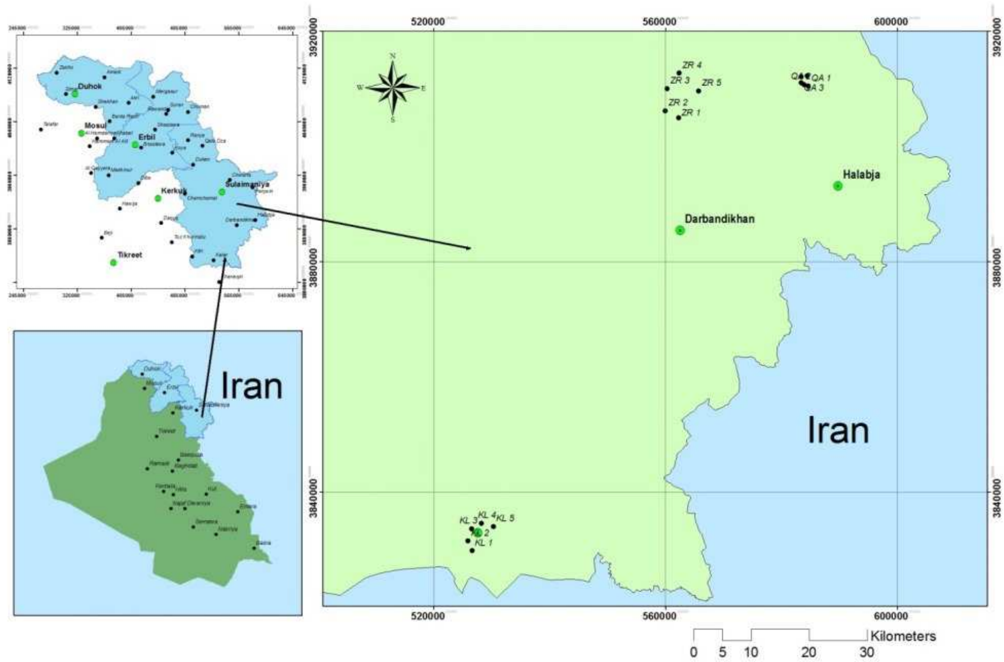

Fig. (1). Studied sample map in Kalar, Qadafery and Zarayan.

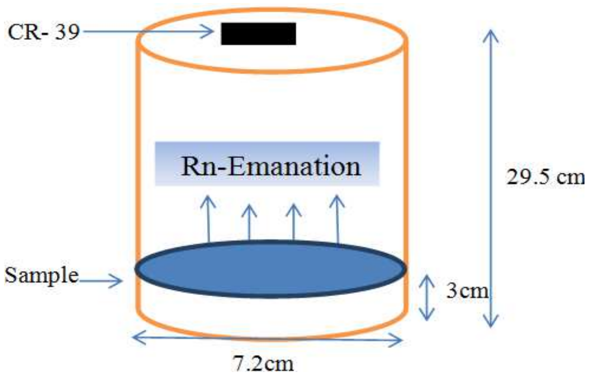

Fig. (2). Schematic Diagram of Long-Tube for SSNTD Technique.

The sample weight were 150 gm prepared after drying and placed on the bottom of a sealed polyethylene bottle (cylindrical plastic) and the (CR-39) detector with pieces of area 1cm x 1.5cm on the other side of cylindrical plastic suspended as shown in Fig. (2), schematic diagram of long-tube, then stored for two months to allow radioactive equilibrium between ^{222}Rn and ^{226}Ra. Exposed detector was collected and etched chemically using 6.25 Molarity NaOH at 70 C^{o} for 6 hours after washing these detectors in distilled water, the track density on CR-39 (tr. /cm^2) was counted using an optical microscope with magnification 400x [8].

2.2. Radon Concentration Measurement

The concentrations of ^{222}Rn in the air in the tube, that contain soil samples by using CR-39, can be calculated from relation [9,10]:

$$C_a = \rho / \eta T \quad (1)$$

where ρ - is the track density on the exposed detector CR-39 (Tr/cm^2).

T - is the exposure time of the samples (60 d)

η - is the detection efficiency (0.05774 Tr/cm^2/d recorded per Bq/m^3)

Then (η) is determined from this relation using the dimensions of the tube [8]:

$$\eta = \frac{1}{4}\, r \left(2 \cos \theta_t - \frac{r}{R_\alpha}\right) \quad (2)$$

where r - is the tube radius for the diffusion volume (3.6 cm).
θ_t - is the threshold angle of the CR-39 detector (35°) [11]
R_α - is the range of α- particle in air from Rn
R_α can be calculated from relation [12]:

$$R_\alpha = (0.005\,E_\alpha + 0.285)\,E_\alpha^{3/2} \quad (3)$$

$$= 4.019 \text{ cm (for energy } E_\alpha = 5.49 \text{ MeV)}$$

The value of the diffusion constant (η) according to the dimensions of the present system equals to (0.057744)Tr.cm^{-2}. d^{-1} / Bq . m^{-3}, where Tr- is a trace , d^{-1} -is day period of time.

To calculate ^{222}Rn concentration in the samples, the following relation can be used [13]:

$$C_s = \frac{\lambda_{Rn}\,C_a\,H\,T}{L} \quad (4)$$

where C_s - is the ^{222}Rn concentration in the samples (Bq\m^3)
C_a – is the ^{222}Rn concentration in air space inside the tube (Bq\m^3)
λ_{Rn} – is the Decay constant of Rn^{222} (0.1814 day^{-1})
H – is the Height of air space in the tube (29.5 cm)
L – is the Thickness of the sample in the tube (3 cm)
T - is the Time of irradiation (60 days)

To calculate the uranium concentrations by ppm must be calculated the number of radon atoms uing relation [12]:

$$A_{Rn} = \lambda_{Rn}\,N_{Rn} \quad (5)$$

From N_{Rn} one can determine the number of atoms of uranium in the samples, using the equation of secular equilibrium [14,15]:

$$\lambda_U\,N_U = \lambda_{Rn}N_{Rn} \quad (6)$$

where λ_U is the decay constant of uranium (4.883x10^{-18} sec^{-1}), the weight of uranium in the samples can be calculated from [16]:

$$W_U = \frac{N_U\,Mu}{N_A} \quad (7)$$

where Mu - is the mass number of uranium ^{238}U
N_A - is the Avogadro number (6.02x10^{23} mol^{-1})

Thus, the concentration of uranium in ppm can be obtained through:

$$C_U\,(ppm) = \frac{W_U}{M_s} * 10^6 \quad (8)$$

where Ms – is the mass of the studied samples.

3. Result and Discussion

We summarized in Table (1) the number of track density ρ (Tr/cm²), the value of radon concentration for air inside the tube C_a (Bq/m) and for soil samples Cs (Bq/m³) with the value of uranium concentration C_U (ppm). The analysis of the measured values shows that there are two positions of Qadqfary's soil samples (Qadafery_2 and Qdafery_5) with high values of radon and uranium concentrations of (145523.227 ± 699.319 and 239980.470 ± 1480.952) Bq/m^3 for radon and (11.052 ± 6.094 and 18.225 ± 12.905) pmm for uranium, also the high values appeared in the soil samples in (Kalar_1, Zarayan_3 and Zarayan_4) with values (85373.627 ± 314.240) Bq/m^3, (102836.414 ± 415.429) Bq/m^{3}and (73731.769 ± 252.208) Bq/m^3 for radon and (6.484±2.738) ppm, (7.810±3.62) pmm and (5.599±2.198) pmm for uranium as shown in the figures (3) and (4), this is due to these regions were agriculture farms and farmers used a fertilizer every years is caused to high concentrations of uranium [17] and according to geology information the soil on type clay and limestone gravel with kometan formation which causes also to high concentrations of uranium [18] while the color of soil in Qadafery (high value) positions was black when the color on the other positions was brown which effect on concentrations [19].

Table (1). *Radon and Uranium concentrations in the soil samples.*

Sample	ρ (Tr/cm²)	C_a (Bq/m)	Cs(Bq/m³)	C_U (ppm)
Kalar1	2763.2	797.691±30.375	85373.627±314.240	6.484±2.738
Kalar2	1444.4	416.975±11.48	44627.123±118.761	3.389±1.035
Kalar3	1507.2	435.104±12.236	46567.433±126.590	3.537±1.103
Kalar4	533.8	154.099±2.579	16492.632±26.681	1.253±0.233
Kalar5	1664.2	480.427±14.197	51418.207±146.876	3.905±1.28
Qadafary1	2323.6	670.785±23.423	71791.459±242.318	5.452±2.112
Qadafary2	4710	1359.700±67.598	145523.227±699.319	11.052±6.094
Qadafary3	2449.2	707.044±25.348	75672.078±262.229	5.747±2.285
Qadafary4	2072.4	598.268±19.729	64030.220±204.105	4.863±1.779
Qadafary5	7767.2	2242.263±143.152	239980.470±1480.952	18.225±12.905
Zarayan1	1884	543.880±17.101	58209.291±176.915	4.421±1.542
Zarayan2	1695.6	489.492±14.601	52388.362±151.053	3.979±1.316
Zarayan3	3328.4	960.855±40.156	102836.414±415.429	7.810±3.62
Zarayan4	2386.4	688.915±24.379	73731.769±252.208	5.599±2.198
Zarayan5	2009.6	580.139±18.839	62089.910±194.898	4.715±1.698
Ave.		741.709±27.234	79382.148±281.748	6.029±2.455
Max.		2242.263±143.152	239980.470±1480.952	18.225±12.905
Min.		154.099±2.579	16492.632±26.681	1.253±0.233

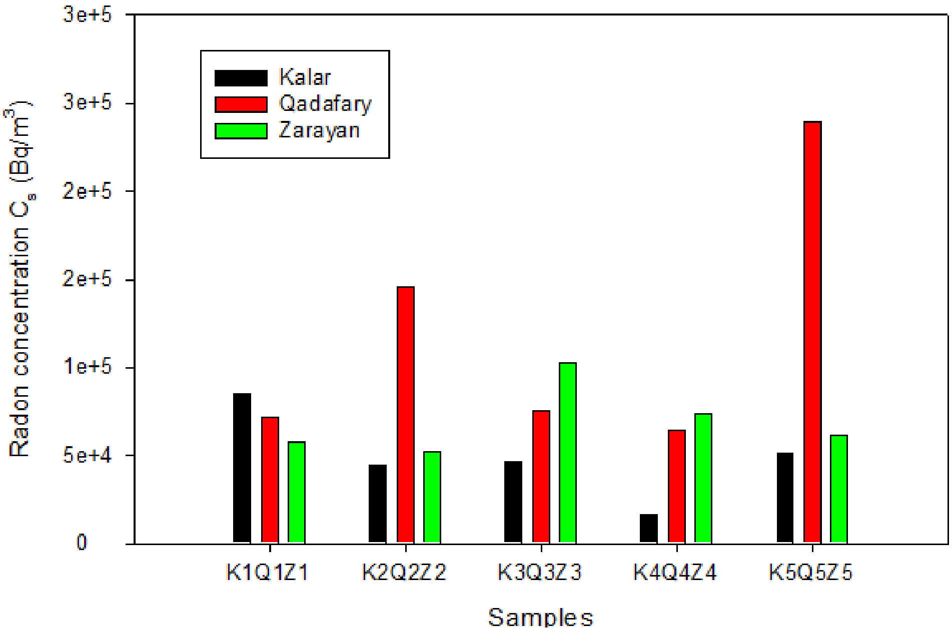

Fig. (3). *Distributions of Radon concentration in the soil samples of Kalar, Qadafary and Zarayan.*

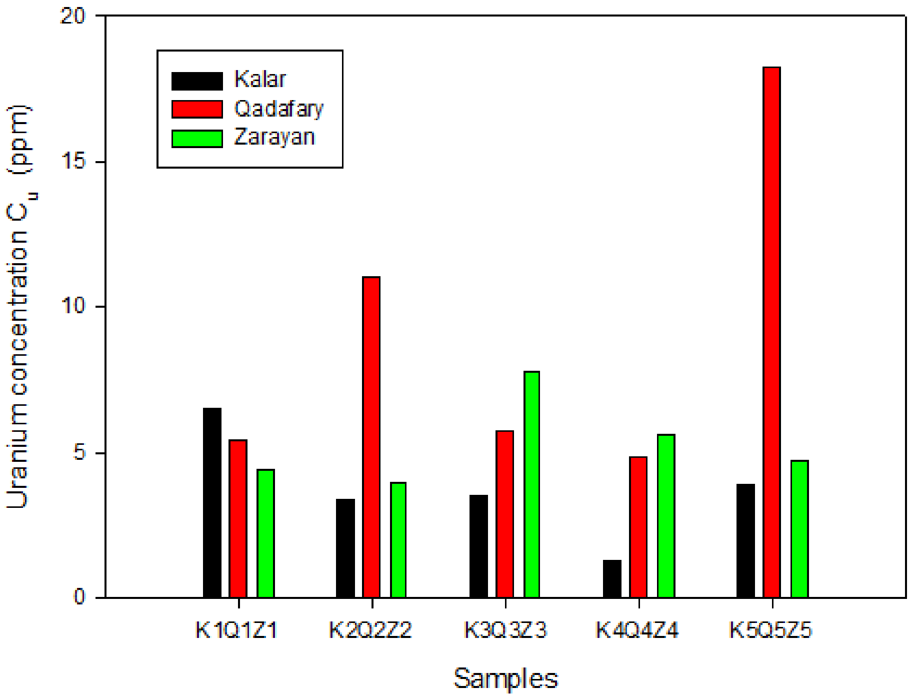

Fig. (4). *Distributions of Uranium concentration in the soil samples of Kalar, Qadafary and Zarayan.*

4. Conclusion

The concentrations of radon and uranium were measured by using a SSNTD technique for 15 soil samples which collected from three regions in Sulaimani area (Qadafery, Kalar and Zarayan). It is concluded that the high concentrations of radon and uranium was in the soil sample Qadafery region more than the others and the reason of higher level concentrations of radon and uranium due to the geology information of these regions.

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