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Measurement of Uranium and Radon Concentrations in Resources of Water from Sulaimany Governorate -Kurdistan Region-Iraq

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ABSTRACT

Different water samples collected from some locations of Sulaimany governorate include deep well rivers, spring and lakes. The concentration of Rn^{222} and U^{238} was measured using Solid State Nuclear Track Detector (SSNTD) as (CR-39). The measured values of Rn^{222} was varies between 6216.406 Bq/m^3 (7.589 Bq/L) and 970.154 Bq/m^3 (1.184 Bq/L), while for U^{238} was between 0.006141 mg/L and 0.000958 mg/L. The maximum value appear in ground waters of locations of deep wells at Gapylon town and deep well of Kanispeka in Sulaimany governorate , these values of concentrations show higher levels in comparing with the international world values, this is due to the composition of soil and rock surrounded the waters in that regions.

Keywords: *Water resources, Rn^{222}, U^{238}, SSNTD, Specific activity, Concentration (ppm)*

1. INTRODUCTION

The principle concept of the process of radioactivity is a spontaneous decay and transformation of unstable atomic nuclei accompanied with the emission of nuclear particles or photons, therefore the analysis of this processes may be found in a wide range of complexities because nuclear radiation can occur in a various types, abundances, and energies, also a given radionuclide may have more than one mode of decay. The presence of appreciable activities of more than one radionuclide in a sample can further complicate analysis [1, 2]

The source from local drinking water utilities or individual wells comes from ground water, streams, rivers, springs or lakes in watershed. Although most water requires some treatment before use, protecting this source is an important part of providing safe drinking water to the civilians. All sources may be affected by a variety contaminates from a variety of activities, when rains falls or snow melts, it picks up and carries away pollutants , depositing them into lakes , rivers , underground sources, these activities have the potential to contaminate the source of drinking water [3].

These resources are important for human life, like used for many industrial activities, also water is a medium for the transport and interaction of radionuclide's with different compartments of the troposphere: soils, sediments, crustal, rocks and air which are continuously exchange their radioactive contents with water, thus radioactivity present in water can reach humans and the environment through many different mechanism [4].

The radiation detector or method of radioactivity analysis requires a good understanding of the properties of nuclear radiation, the mechanisms of interaction of radiation with matter, half-life, decay schemes, decay abundances, and energies of decay. Form the basis for the methods of detection and measurement of radionuclides and understanding of the concepts of radiation detection and measurement [5, 1]. It is necessary to explain the method used in this study, which was Solid State Nuclear Track Detector (SSNTD) technique using CR-39 detector to identify concentrations of radioactive isotopes like Radon and Uranium.

Due to it is long half life time related to other isotopes, radon (Rn^{222}) has half life (3.82 d) which is considered to be the most significant isotope in decay series of U^{238} , this is show the radon problem in the environmental studies, because tracing of U^{238} are found in most natural rocks, soil and water. It can be measured using SSNTD (Solid State Nuclear Track Detector) technique [6].

The plastic SSNTD detectors are most widely used because they are more sensitively than crystal and glass. This type, like CR-39 polymer (a polly allydiglycol) Carbonate can record all charged radiations, the basis of this technique lies in the fact when heavy charged particle traverse a dielectric medium, they are able to leave long – lived trails of damage (tracks) ,when the shape and type of damage position(tracks) on the film plastic detector depend on the mass, energy, the charge of the incident particle and on the type of solid state detector[7] and these tracks may be observed either by transmission electron microscopy or under an ordinary optical microscope after enlargement by etching process using NaOH for 6 hrs at 70 C^o temperature [4].

2. EXPERIMENTAL TECHNIQUE AND CALCULATION

In this study, variety of samples were collected at different resources of water as deep well , rivers, spring and lakes in some locations at Sulaimanya governorate shown in figues (1 and 2) [8], like (Shahrbazher , Shahrazor , Pshdar and Sulaimany center with their towns), table(1) explains these locations and their codes :

For the measurement of Radon concentration using this technique which was shown in fig (3), it's necessary to determine the diffusion constant(K) for the system from this relation[9]:

$$\rho = K\, C_a\, T \qquad (1)$$

Table 1: Water Samples Location and their Codes

No	Location	Cods
1	Mamayara (beer)	W1B
2	Zargata (beer)	W2B
3	Hajy Rahim (beer)	W3B
4	Qadamkher (beer)	W4B
5	Kanispeeeka (beer)	W5B
6	Ali kamal (beer)	W6B
7	Hajy Aziz (beer)	W7B
8	Taina l (beer)	W8B
9	Qrga (beer)	W9B
10	Kurdsat (beer)	W10B
11	Kalakn (beer)	W11B
12	Bazyan (beer)	W12B
13	Sruchk (beer)	W13B
14	Penjween (beer)	W14B
15	Byara (beer)	W15B
16	Halabja (beer)	W16B
17	Hajyawa (beer)	W17B
18	Bingird (beer)	W18B
19	Gapylon (beer)	W19B
20	Hajy Bag (karez)	W20K
21	Tainal (karez)	W21K
22	Sywayl (karez)	W22K
23	Mawat (karez)	W23K
24	Barzinja (karez)	W24K
25	Sewsenan (karez)	W25K
26	Betwata (karez)	W26K
27	Penjween (kani)	W27K
28	Byara (kani)	W28K
29	Ahmadawa (shakh)	W29S
30	Hero (shakh)	W30S
31	Penjween (shakh)	W31S
32	Esewa (shakh)	W32S
33	Qaladize (shakh)	W33S
34	Halsho (shakh)	W34S
35	Surchnar	W35L
36	Saidsadiq (Sarchaway Zalm)	W36L
37	Ranya (Qula)	W37L
38	Arbat (Bestan soor)	W38L
39	Serwan (Lake)	W39L
40	Dukan (Lake)	W40L

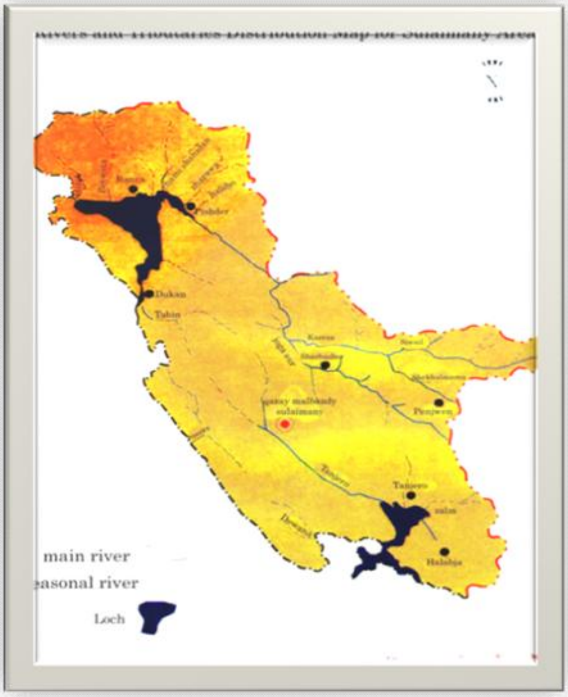

Fig 1: Rivers and tributaries distribution map for Sulaimany area

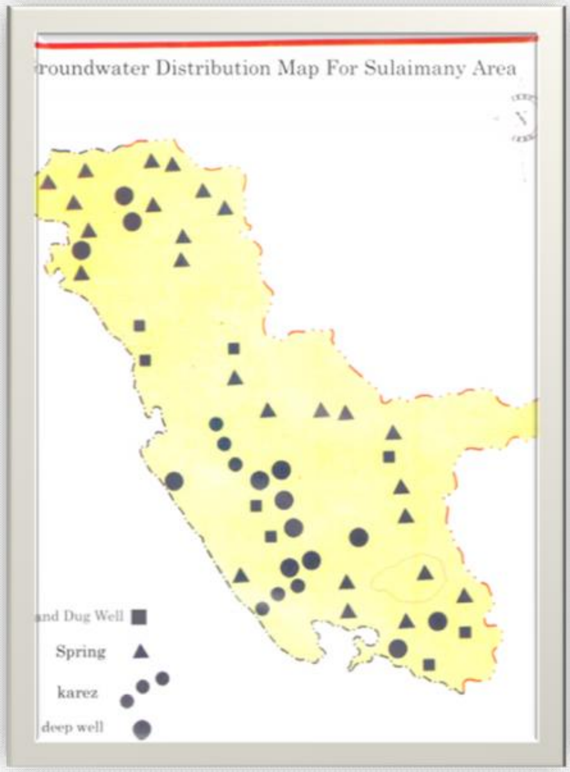

Fig 2: Groundwater distribution map for Sulaimany area

Where ρ - Track density Tr\cm^2
K - Diffusion constant
C_a - Rn concentradim in air space (B\cm^3)
T- Radiate time
D - Average of track density (Tr\hr.cm^2)

Diffusion constant (K) could be determine from this relation due to the dimensions of the technique [10]:

$$K = 1/4 \ (r)[2\cos \theta_t - r\backslash R_\alpha] \qquad (2)$$

Where
r - tube radius for the diffusion volume (3.6cm)
θ_t - threshold angle for the CR-39 detector (35^o) ,[7]
R_α - range of – particle in air from Rn
R_α can be calculated from this relation [2]:

$$R=(0.005\ E_\alpha + 0.285)\ E_\alpha^{3/2} \qquad (3)$$
= 4.15cm

Then the value of (K) diffusion constant according to dimensions of this system equal to

0.057744 Tr.cm^{-2} .hr^{-1} / Bq . m^{-3}

To calculate Rn concentration in the samples by using this relation [11]:

$$C_s = \lambda_{Rn}\ C_a\ H\ t \ \backslash\ L \qquad (4)$$

Where C_s - Rn concentration in the samples (Bq\m3)
C_a - Rn concentration in air space (Bq\m3)
λ_{Rn} - decay constant for Rn (0.1814 day)
H – height of air space in the tube (29.5cm)
L – thickness of the sample in the tube (3cm)
t- time of radiate (60 days)

The activity of Radon in the sample (A_{Rn}) could be determined through this relation [12]:

$$A_{Rn} = C_s\ V \qquad (5)$$

Where A_{Rn} - activity of Radon
V - the volume of sample ($V = \pi r^2L$) $=122.0832$ cm^3

For uranium concentration may be determined through the number of atoms of radon:

$$A_{Rn} = \lambda_{Rn}\ N_{Rn} \qquad (6)$$

Using the equation of secular equilibrium one can determine the number of atoms of uranium in the samples:

$$\lambda_u\ N_u = \lambda_{Rn}\ N_{Rn} \qquad (7)$$

Where λ_u is decay constant of uranium ($4.883\text{x}10^{-18}$ sec^{-1}), then the weight of uranium in the samples could be calculated from:

$$w_u = N_u\ At_u\ /\ N_{avo.} \qquad (8)$$

Where At_u - mass number of uranium U238
N_{avo} - Avogadro number ($6.02\text{x}10^{23}$ mol $^{-1}$)

To calculate the concentration of uranium by ppm C_u(ppm):

$$C_u(ppm) = W_u\ /\ W_s \qquad (9)$$

Where Ws – mass of samples which is used.

In this work, the SSNTD technique used a plastic detector CR-39 depending on the extend time for detecting emitted α-particle from the Rn^{222} gas of the soil samples which produced from the natural decay of U^{238}. The CR-39 detectors of thickness 500 µm were cutting by (1x1.5) cm then exposed to (100 ml) of water samples inside the tube as shown in fig .(3)

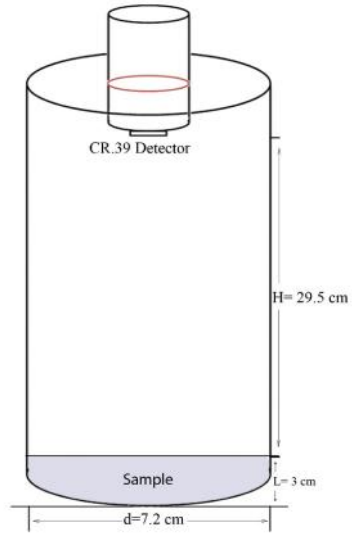

Fig 3: Long-tube for SSNTD technique

After closing these tubes perfectly they stored for 60 days, then the CR-39 detectors removed from the tube and chemically etched using molarities (6.25M) of NaOH [13]:

$$C_{sol} = W_{Naoh}\ \ 1000\ /\ \ W_{at.}\ \ V_{wate} \qquad (10)$$

Where W_{Naoh} - weight of NaoH (62.5gm)
W_{at} - atomic weight of NaOH (40)
V_{water} = volume of distilled water (250ml)

The etching process continues for 6 hrs at temperature 70C^o after washing and drying the detectors we can observe the trace of α –particles with high deep on a CR-39 plastic detector using the optical microscope (Olympus) with magnification power 400x [4].

Table (2) shows the tracking density of α–particles, Rn-concentration in air space inside the tube

and in water samples, also the concentrations of uranium
:

Table 2: Rn^{222} and U^{238} Concentration in Water Samples using SSNTD technique

Samples	ρ(Tr/cm²)	Ca(Bq/m³)	Cs((Bq/m³)	As(Rn)Bq/L	U mg/L
W1B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W2B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W3B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W4B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W5B	201.2	58.083	6216.406	7.589±0.535	0.006140±0.00043
W6B	37.7	10.883	1164.804	1.422±0.231	0.001150±0.00018
W7B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W8B	31.4	9.065	970.155	1.184±0.211	0.000958±0.00017
W9B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W10B	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W11B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W12B	31.44	9.076	971.391	1.185±0.211	0.000959±0.00017
W13B	31.4	9.065	970.155	1.184±0.211	0.000958±0.0017
W14B	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W15B	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W16B	113.1	32.650	3494.411	4.266±0.401	0.003451±0.0003
W17B	188.64	54.457	5828.344	7.115±0.518	0.005757±0.00041
W18B	201.2	58.083	6216.406	7.589±0.535	0.006140±0.00043
W19B	201.2	58.083	6216.406	7.589±0.535	0.006140±0.00043
W20K	94.3	27.223	2913.554	3.556±0.366	0.002878±0.00029
W21K	125.7	36.288	3883.709	4.741±0.422	0.003836±0.00034
W22K	31.4	9.065	970.155	1.184±0.211	0.000958±0.0017
W23K	113.184	32.674	3497.007	4.269±0.401	0.003454±0.00032
W24K	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W25K	94.32	27.229	2914.172	3.557±0.366	0.002878±0.00029
W26K	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W27K	188.64	54.457	5828.344	7.115±0.518	0.005757±0.00041
W28K	188.64	54.457	5828.344	7.115±0.518	0.005757±0.00041
W29S	94.32	27.229	2914.172	3.557±0.366	0.002878±0.00029
W30S	188.64	54.457	5828.344	7.115±0.518	0.005757±0.00041
W31S	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W32S	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W33S	94.32	27.229	2914.172	3.557±0.366	0.002878±0.00029
W34S	31.4	9.065	970.155	1.184±0.211	0.000958±0.0017
W35L	94.32	27.229	2914.172	3.557±0.366	0.002878±0.00029
W36L	125.76	36.305	3885.563	4.743±0.422	0.003838±0.00034
W37L	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W38L	62.8	18.129	1940.310	2.368±0.298	0.001916±0.00024
W39L	157.2	45.381	4856.954	5.929±0.472	0.004797±0.00038
W40L	188.64	54.457	5828.344	7.115±0.518	0.005757±0.00041

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3. OTHER WORKS

Table (3) explains the concentrations of U^{238} and Rn^{222} , in other international works for water samples, shows most of the results by these works, they are within the range of standard values from IAEA, EPA and UNSCEAR reports except in some work the maximum range are some higher, for example, in Jordan samples [14] there was a high value of Rn concentration, this may due to a thick phosphate beds located at the bottom of the well and the main aquifer in the study regions is the kurnub sandstone partially interconnected with the underline sandstone, this aquifer may contains plant remains and black shale combined with relatively high concentrations of uranium, which may dissolved by water flowing through these beds. In some other work the high concentrations of natural radionuclides may be due to rock and soil contain uranium which surrounding water source and is highly affects the water samples, so high concentration of radionuclides because the stream and river waters continuously flow in their bed and they are in contact with the surrounding soil and rock, then radionuclides in surrounding enter the stream and river waters[15,16].

Table 3: U^{238} and Rn^{222} Concentrations in Other Works for Water Samples

Samples	U^{238}	Rn^{222}	References
well		(3.1 - 5.7) Bq/L	14
drinking water		(2.5 - 4.7) Bq/L	14
Sea water		(4.3 - 6.3) Bq/L	14
Well water (region 1)		(1.8 - 5.3)Bq/L	17
Well water (region 2)		(2.7 – 6.3)Bq/L	17
Drinking water	(1.48±0.12) ppm		18
Mineral water	(2.16±0.15) ppm		18
sea	3.2 µg/L		19
Lake-fresh	2.1 µg/L		20
Lake- salt	22.3 µg/L		20
surface-total	6 µg/L		20
surface water	0.0254 µg/L	(0.07-157) Bq/L	20
surface river	(0.0055-0.4)Bq/L	(1.5 - 4.4) Bq/L	20
ground water	2.95 µg/L		20
ground water	0.0015 mg/L	175 Bq/L	20
ground water	(0.0004-1340)µg/L	(0.03 - 29500)Bq/L	20
ground water(bedrock)	13.7 µg/L	311 Bq/L	20
ground water(overburden)	0.846 µg/L	37.8 Bq/L	20
surface water	12	(1 - 100) Bq/L	21

4. DISCUSSION

The measurement of Rn^{222} concentrations in water samples using SSNTD technique and the calculations of U^{238} explained in the table (2).

The average value of Rn^{222} in well water was 2258.252 Bq/m^3 (2.756 Bq/L) , and for U^{238} is 0.002231 mg/L, while the maximum value for Rn ^{222} was 6216.406 Bq/m^3 (7.589 Bq/L) , and for U^{238} is 0.006141 mg/L, the minimum value for Rn ^{222} was 970.154 Bq/m^3 (1.184 Bq/L), and for U^{238} is 0.000958 mg/L.

The average value of Rn^{222} in karez water was 2873.745 Bq/m^3 (3.508 Bq/L) , and for U^{238} is 0.002639 mg/L, while the maximum value for Rn ^{222} was 5828.344 Bq/m^3 (7.115 Bq/L) , and for U^{238} is 0.005757 mg/L, the minimum value for Rn ^{222} was 970.154 Bq/m^3 (1.184 Bq/L) , and for U^{238} is 0.000958 mg/L.

The average value of Rn^{222} in water from mountains (rivers) was 2589.757 Bq/m^3 (3.161 Bq/L) , and for U^{238} is 0.002558 mg/L, while the maximum value for Rn ^{222} was 5828.344 Bq/m^3 (7.115 Bq/L), and for U^{238} is 0.005757 mg/L, the minimum value for Rn ^{222} was 970.154 Bq/m^3 (1.184 Bq/L), and for U^{238} is 0.000958 mg/L.

The average value of Rn^{222} in lake water was 3885.150 Bq/m^3 (4.743 Bq/L), and for U^{238} is 0.003838 mg/L, while the maximum value for Rn ^{222} was 5828.344 Bq/m^3 (7.115 Bq/L), and for U^{238} is 0.005757 mg/L, the minimum value for Rn ^{222} was 1940.309 Bq/m^3 (2.368 Bq/L), and for U^{238} is 0.0001917 mg/L.

Comparing these results with the all values given by IAEA and EPA reports[19,20,22]], it is clear that the high concentrations appear in the well water samples of

W10B, W14B, W16B, W19B, in Karez water samples W21K, W22K, W23K, W27K, in water samples from mountains(rivers) W34S and in lake water samples W35L, W37L, W39L and W40L.

The measurement of radioactivity in drinking water allows the determinations of radiation exposure of the population from the most common source of consumed water as natural waters contain α–emitters and β-emitters, therefore, it is necessary to have information about concentration of radionuclides in drinking water, when concentration of radionuclide in groundwater depend mainly on the kind of mineral surrounded, the chemical composition of the water, the water flow rate and the soil ions retention [23] .

According to the fig.(4) which explain the contour line [24] of the regions and shown different elevations of our sample locations for examples, locations of waters coming from mountains making (small river) and groundwater when some of them different from those regions which have taken soil samples, these different elevations of locations may effected by weathering due to flow of water at a high speed and holding rocks with high activity of concentrations causing to increase concentrations.

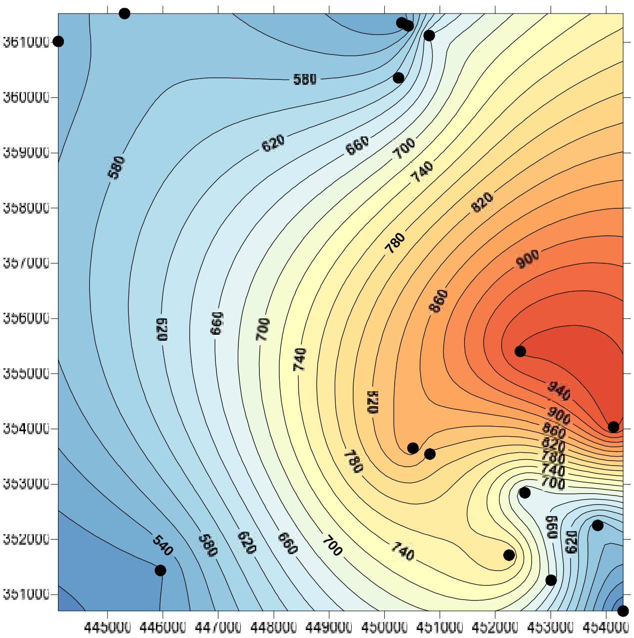

Fig 4: Contour line of water samples locations in Sulaimany area

According to international value in China [20] the concentration of natural radionuclide in salt water was higher than the values at sweet water, but in water of Kurdistan region especially in area of Sulaimany governorate, although they are sweet water there are some location with high concentrations. The concentration, in some water samples, of Rn^{222} is higher than the value of concentrations recommended by the WHO guideline which were (0.1 – 1) Bq/L [25], the high values appear in well water of W18B (Bingird) at deep 70 m , W19B (Gapylon) at deep 30 m, W16B (Halabja) at deep 120 m , W14B (Penjween) at deep 70 m and in some locations of sulaimany center like W10B (kurdsat) at deep 50 m and W5B (kanispeeka) at deep 130 m.,

About the spring water samples, the high values appear in W27K (Penjween), W21K (Tainal), W23K (Mawat), W26K (Betwata) and W28K (Byara), in water comes from mountains (rivers) appear in all the samples especially in W30S (Hero), W31S (Penjween) and W32S (Esewa) except in samples W34S (Hasho) was low value. For lake water also the high value appear in samples W40L (Dukan), W39L (Serwan), W36L (Zalm) and W37L (Ranya) because this lake act as a reservoir collecting water from different positions especially from mountains or big spring water having high level of radiation from mineral granite rock surrounded water [14, 26] also when the water flows from mountains holding small rocks with high activity may effect on water at these regions.

5. CONCLUSION

From water samples in Sulaimany governorate which include deep well, spring, rivers and lakes using Solid State Nuclear Track Detector(SSNTD) technique, the average value concentrations of Rn^{222} in well water was 2258.252 Bq/m^3 (2.756 Bq/L) , and for U^{238} is 0.002231 mg/L , in karez water was 2873.745 Bq/m^3 (3.508 Bq/L) , and for U^{238} is 0.002639 mg/L, the average value of Rn^{222} in water from mountains (rivers) was 2589.757 Bq/m^3 (3.161 Bq/L), and for U^{238} is 0.002558 mg/L, and the average value of Rn^{222} in lake water was 3885.150 Bq/m^3 (4.743 Bq/L) and for U^{238} is 0.003838 mg/L. By comparing these results with the all values given by IAEA and EPA reports, it is clear that the high concentrations appear in the well water samples of W10B, W14B, W16B, W19B, in Karez water samples W21K, W22K, W23K, W27K , in water samples from mountains W34S and in lake water samples W35L, W37L, W39L and W40L.

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