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Measurement of Natural radioactivity in tap water samples for selected regions in Thi-Qar Governorate - Iraq

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ABSTRACT

In the present work, we have measured specific activity concentrations in ten tap water samples for selected regions in Thi-Qar governorate by using high purity germanium (HPGe) detector. The results have shown that, the specific activity, for ^{238}U was ranged from (0.65±0.8 Bq/kg) in AL- Nasir region to (1.32±0.7.8 Bq/kg) in AL-Refai region, for ^{232}Th the specific activity was ranged from (0.120±0.34 Bq/kg) in AL-Garraf region to (0.980±0.99 Bq/kg) in AL- Dwaya region, for ^{40}K the specific activity was ranged from (13.33±3.6 Bq/kg) in AL-Nasir region to (38.54±6.2 Bq/kg) in (AL-Garraf) region, with an average values of (0.933±0.16 Bq/kg), (0.737±0.17 Bq/kg), (24.451±7.5Bq/kg), for ^{238}U, ^{232}Th and ^{40}K, respectively. In order to asses the radiological hazards of the radioactivity in tap water, we have been calculated the parameters (Ra_{eq} , D_{γ}, AED_{in} , AED_{out} , EAD , I_{γ} , H_{in} and H_{ex}).

Keywords**:** (HPGe) detector; Thi-Qar governorate; tap water; specific activity; radionuclides

1. INTRODUCTION

Radon (^{222}Rn) is a natural inert radioactive tasteless and odorless gas, whose density is 7.5 times higher than that of air. It dissolves in water and can readily diffuse with gases and water vapor, thus building up significant concentrations [1]. The source of naturally occurring radionuclides is the earth's crust. Among these radionuclides there exist three radioactive series originating from ^{238}U, ^{235}U and ^{232}Th being one of the most abundant sources of naturally occurring radioactivity, the ^{238}U series has been widely investigated. Exposure to radionuclides from drinking water results in the increased risk of cancer.

The radioactive particles alpha, beta and gamma photons emitted by radionuclides are called ''ionizing radiation'' because they ionize ''destabilize'' nearby atoms as they travel through a cell or other material. In living tissue, this ionization process can damage chromosomes or other parts of the cell. This cellular damage can lead to the death of the cell or to unnatural reproduction of the cell. Exposure to elevated uranium levels in drinking water has been shown to lead to changes in kidney function that are indicators of potential future kidney failure [2].

The aim of the present work is to determine the specific activity concentrations of (^{238}U, ^{232}Th and ^{40}K), radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose rates, external annual effective dose, activity concentration index, internal and external hazard indicies in tap water samples for some selected regions in Thi-Qar governorate by using (HPGe) detector.

2. MATERIALS AND METHODS

Collection and Preparation of the samples

Tap water samples were obtained from the water networks in dwellings from different locations in Thi-Qar governorate, (1 litter) Marinelli beaker, the sealed marinelli beaker were kept for one month before measurements in order to achieve the secular equilibrium for 238U and 232Th with their respective progenies [3]. The procedure of the detector is to produce a signal for the incident gamma-ray on the detector generates a linear charge pulse, which is delivered to the preamplifier. The (HPGe) detector (CANBERA-model 7229N, USA) with an efficiency of 40% and energy resolution (2.6 keV) at energy (1332.6 keV) for 60Co, the high purity N-type semiconductor detector with physical characteristics of (geometry closed-end coaxial, (3×3 inch).

The (HPGe) detector is kept cold by immersing it in a liquid-nitrogen vessel at (-196 °C) to reduce the leakage current to acceptable levels. The detector is surrounded by lead shield of about 10 cm thickness to reduce the background radiation. An essential requirement for the measurement of gamma emitter is the exact identity of photo peaks present in a spectrum produced by the detector system.

The energy calibration of germanium detector system was made by measuring the standard sources of known radionuclide with well-defined energies with the energy of interest. The Energy calibration source should be counted long enough to produce well-defined photo peaks. The energy calibration by using the standard source of 1 litter marinelli beaker of Europium (^{152}Eu), which has been prepared in this work with energies (121.8, 244.7, 344.3, 411.1, 444.6, 778.9, 964.0, 1085.8, 1112.0 and 1408.0 keV), as shown in Figure (1).

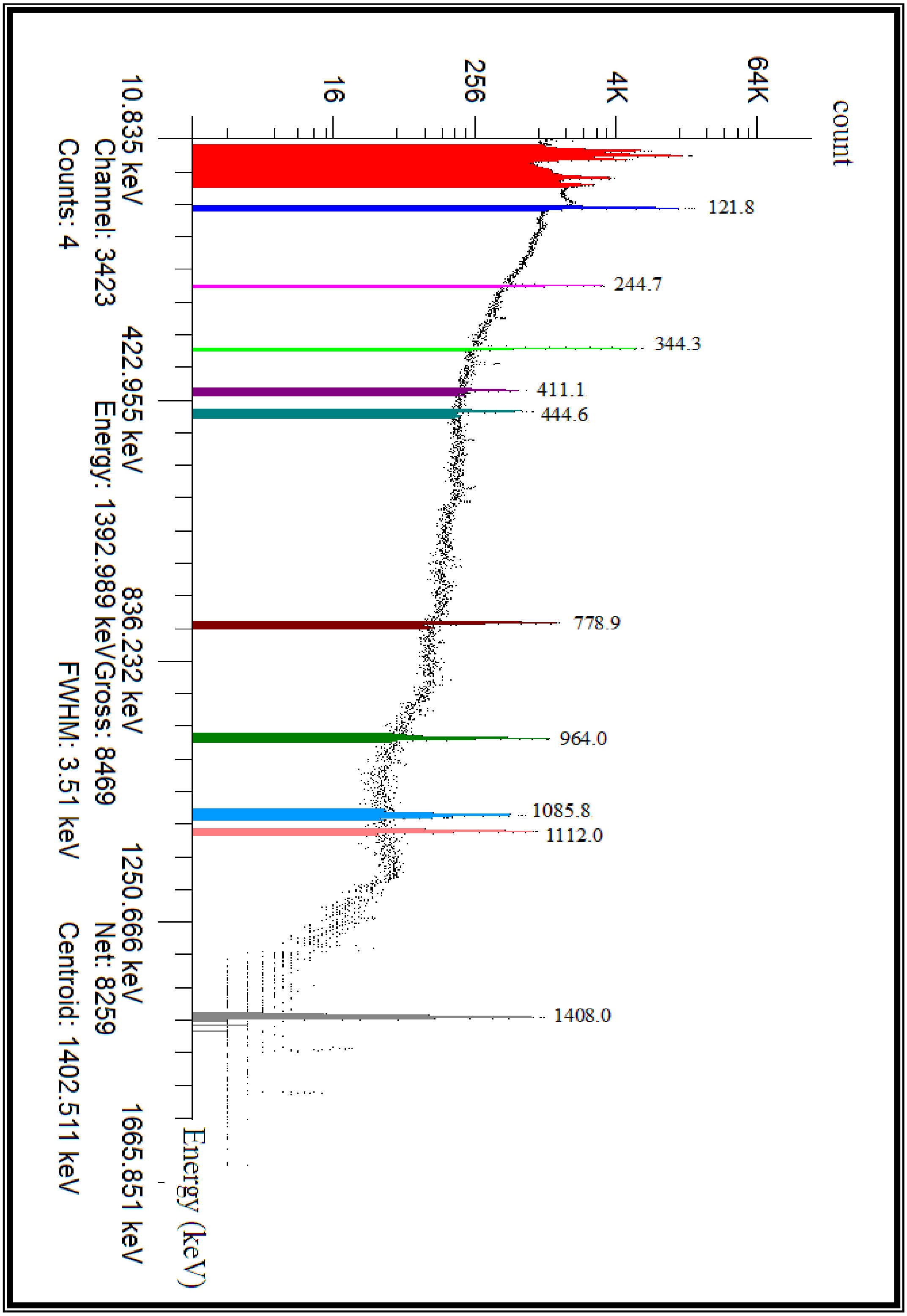

Figure 1. ^{152}Eu spectrum of the prepared standard source.

The specific activity concentration of radionuclides in tap water samples was measured by the equation [4]:

$$A = (Net \cdot Area - B.G)/W \times I_{\gamma}(E\gamma) \times eff \times T \qquad (1)$$

where: B.G: Background activity.

A: specific activity concentration of radionuclides measured in (Bq/kg),W: Weight of the tap water sample measured (kg), eff: efficiency of the detector, $I_{\gamma}(E_{\gamma})$: abundance at energy E_{γ} and T is the time of measurement which is equal to (7200 s). To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index called radium equivalent activity (Ra_{eq}) is used to ensure the uniformity in the distribution of natural radionuclides ^{238}U, ^{232}Th and ^{40}K and is given by the expression [5]:

$$Ra_{eq}\,(Bq/kg) = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

where: A_U, A_{Th} and A_K are the specific activities concentrations of ^{238}U, ^{232}Th and ^{40}K in (Bq/L). Outdoor air gamma absorbed dose rate (D_{γ}) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface which can be computed from specific activities A_U, A_{Th} and A_K of ^{238}U, ^{232}Th and ^{40}K in (Bq/L) respectively using the following relation [6]:

$$D_{\gamma}\,(nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \qquad (3)$$

The estimated annual effective dose equivalent received by a member was calculated by using a conversion factor of (0.7 Sv/Gy),which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20 % and 80 % for indoors [7]:

$$(AED)\text{ in }(mSv/y) = D_{\gamma}\,(nGy/h) \times 10^{-6} \times 8760\ h/y \times 0.80 \times 0.7\,Sv/Gy \qquad (4)$$

$$(AED)\text{ out }(mSv/y) = D_{\gamma}\,(nGy/h) \times 10^{-6} \times 8760\ h/y \times 0.20 \times 0.7\,Sv/Gy \qquad (5)$$

The external annual effective dose was calculated by using the following equation [8]:

$$EAD = (0.92A_U + 1.1A_{Th} + 0.08A_K) \times (10^{-9}\ Gy/h) \times (0.7\ Sv/Gy) \times (24 \times 365)\ h/y \times 0.8 \qquad (6)$$

The activity index (I_{γ}) for water samples was calculated by using the following equation [8]:

$$I_{\gamma} = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \qquad (7)$$

where A_U, A_{Th} and A_K are the specific activities concentrations values of, ^{238}U, ^{232}Th and ^{40}K respectively. The measured internal hazard index (H_{in}) is given by the following equation [9]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (8)$$

This index value must be less than unity in order to keep the radiation hazard to be insignificant. The measured external hazard index (H_{ex}) is given by the following equation [7]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (9)$$

3. RESULTS AND DISCUSSION

The results of the present work are summarized in Tables (1-a) and (1-b), it can be noticed that the highest value of specific activity concentration of (^{238}U) was found in (AL-Refai) region which was equal to (1.32±0.7 Bq/L), while the lowest value of specific activity concentration of (^{238}U) was found in AL-Nasir region which was equal to (0.65±0.8 Bq/L) as showing in figure (2) and with an average value of (0.933±0.16 Bq/L) as showing in figure (3). The highest value of specific activity concentration of (^{232}Th) was found in (AL-Dwaya) region which was equal to (0.980±0.99 Bq/L) as showing in figure (4), while the lowest value of specific activity concentration of (^{232}Th) was found in (AL-Garraf) region which was equal to (0.120±0.34 Bq/L), with an average value of (0.737±0.17 Bq/L).

The highest value of specific activity concentration of (^{40}K) was found in (AL-Garraf) region which was equal to (38.54±6.2 Bq/L), while the lowest value of specific activity concentration of (^{40}K) was found in (AL-Nasir) region which was equal to (13.33±3.6 Bq/L), with an average value of (24.451±7.5 Bq/L). From Table (2) it can be noticed that: The highest value of radium equivalent (Ra_{eq}) was found in (AL-Dwaya) region which was equal to (5.273 Bq/L), while the lowest value of radium equivalent was found in (AL-Refai) region which was equal to (0.633 Bq/L), with an average value of (3.41±0.81 Bq/L).

The highest value of absorbed dose rate (D_γ) was found in (AL-Dwaya) region which was equal to (2.605 nGy/h), while the lowest value of absorbed dose rate was found in (AL-Refai) region which was equal to (0.292 nGy/h), with an average value of (1.67±0.42 nGy/h). The highest value of indoor annual effective dose $(AED)_{in}$ was found in (AL-Dwaya) region which was equal to (0.013 mSv/y) , while the lowest value of indoor annual effective dose was found in (AL-Refai) region which was equal to (0.001 mSv/y), with an average value of (0.008±0.002 mSv/y).

The highest value of outdoor annual effective dose $(AED)_{out}$ was found in (AL-Dwaya) region which was equal to (0.003 mSv/y), while the lowest value of outdoor annual effective dose was found in (AL-Refai) region which was equal to (0.0009 mSv/y), with an average value of (0.002±0.004 mSv/y). The highest value of external annual effective dose (EAD) was found in (AL-Dwaya) region which was equal to (0.024 mSv/y) , while the lowest value of external annual effective dose was found in (AL-Refai) region which was equal to (0.003 mSv/y), with an average value of (0.016±0.004 mSv/y). The highest value of activity concentration index (I_γ) was found in (AL-Dwaya) region which was equal to (0.021), while the lowest value of activity concentration index was found in (AL-Refai) region which was equal to (0.002), with an average value of (0.013±0.003).

The highest value of internal hazard index (H_{in}) was found in (AL-Dwaya) region which was equal to (0.017), while the lowest value of internal hazard index was found in (AL-Refai) region which was equal to (0.003), with an average value of (0.012±0.003). The highest value of external hazard index (H_{ex}) was found in (AL-Dwaya) region which was equal to (0.014), while the lowest value of external hazard index was found in (AL-Refai) region which was equal to (0.007), with an average value of (0.01±0.002).

Table 1(a). The specific activities of radionuclides (Bq/L) in ground water samples in Thi-Qar governorate.

Regions	**^{238}U (Bq/L)**	**^{232}Th (Bq/L)**	**^{40}K (Bq/L)**	**Ra_{eq} (Bq/L)**	**D_{γ} (nGy/h)**
AL-Refai	1.32±0.7	0.940±0.04	32.20±5.6	0.633	0.292
Qulat Sikar	0.91±0.9	0.820±0.9	22.24±4.7	3.795	1.843
AL-Shatra	0.68±0.8	0.910±0.95	18.24±4.2	3.386	1.624
AL-Fajr	0.86±0.9	0.670±0.81	28.17±5.3	3.987	1.977
AL-Hammar	0.93±0.9	0.820±0.9	16.22±4.0	3.352	1.601
AL-Fuhud	0.85±0.9	0.710±0.84	16.45±4.0	3.132	1.508
AL-Nasir	0.65±0.8	0.570±0.75	13.33±3.6	2.492	1.200
AL-Dwaya	1.05±1	0.980±0.99	36.64±6.0	5.273	2.605
AL-Garraf	1.24±1.1	0.120±0.34	38.54±6.2	4.379	2.252
AL-Nasiriyah	0.84±0.9	0.830±0.91	22.48±4.7	3.758	1.827
Average	**0.933±0.16**	**0.737±0.17**	**24.451±7.5**	**3.41±0.81**	**1.67±0.42**

Table 1(b). The specific activities of radionuclides (Bq/L) in ground water samples in Thi-Qar governorate.

(A.E.D) (mSv/y)		EAD (mSv/y)	I_{γ}	Hazard index	
Indoor E_{in}	Outdoor E_{out}			H_{in}	H_{ex}
0.001	0.000	0.003	0.002	0.003	0.007
0.009	0.002	0.017	0.015	0.013	0.010
0.008	0.002	0.015	0.013	0.011	0.009
0.010	0.002	0.019	0.016	0.013	0.011
0.008	0.002	0.015	0.013	0.012	0.009
0.007	0.002	0.014	0.012	0.011	0.008
0.006	0.001	0.011	0.009	0.008	0.007
0.013	0.003	0.024	0.021	0.017	0.014
0.011	0.003	0.021	0.018	0.015	0.012
0.009	0.002	0.017	0.014	0.012	0.010
0.008±0.002	**0.002±0.004**	**0.016±0.004**	**0.013±0.003**	**0.012±0.003**	**0.01±0.002**

4. CONCLUSIONS

This study showed that the analyzed tap water samples by using high purity germanium (HPGe) detector from different regions in Thi-Qar governorate. The average natural specific activity concentrations in (^{238}U, ^{232}Th and ^{40}K) which was equal to (0.933±0.16 Bq/L), (0.737±0.17 Bq/L) and (24.451±7.5 Bq/L), respectively.

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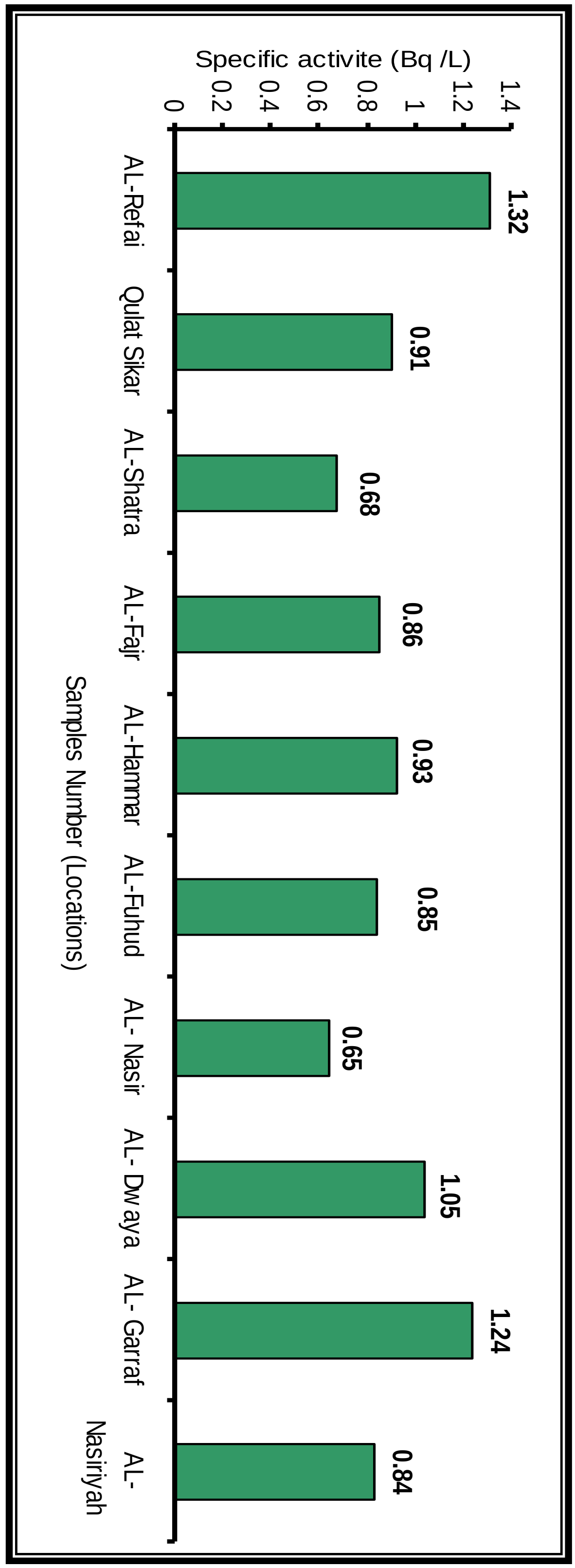

Figure 2. A histogram illustrating the change specific activity concentrations of ^{238}U for all the regions studied in Thi-Qar governorate.

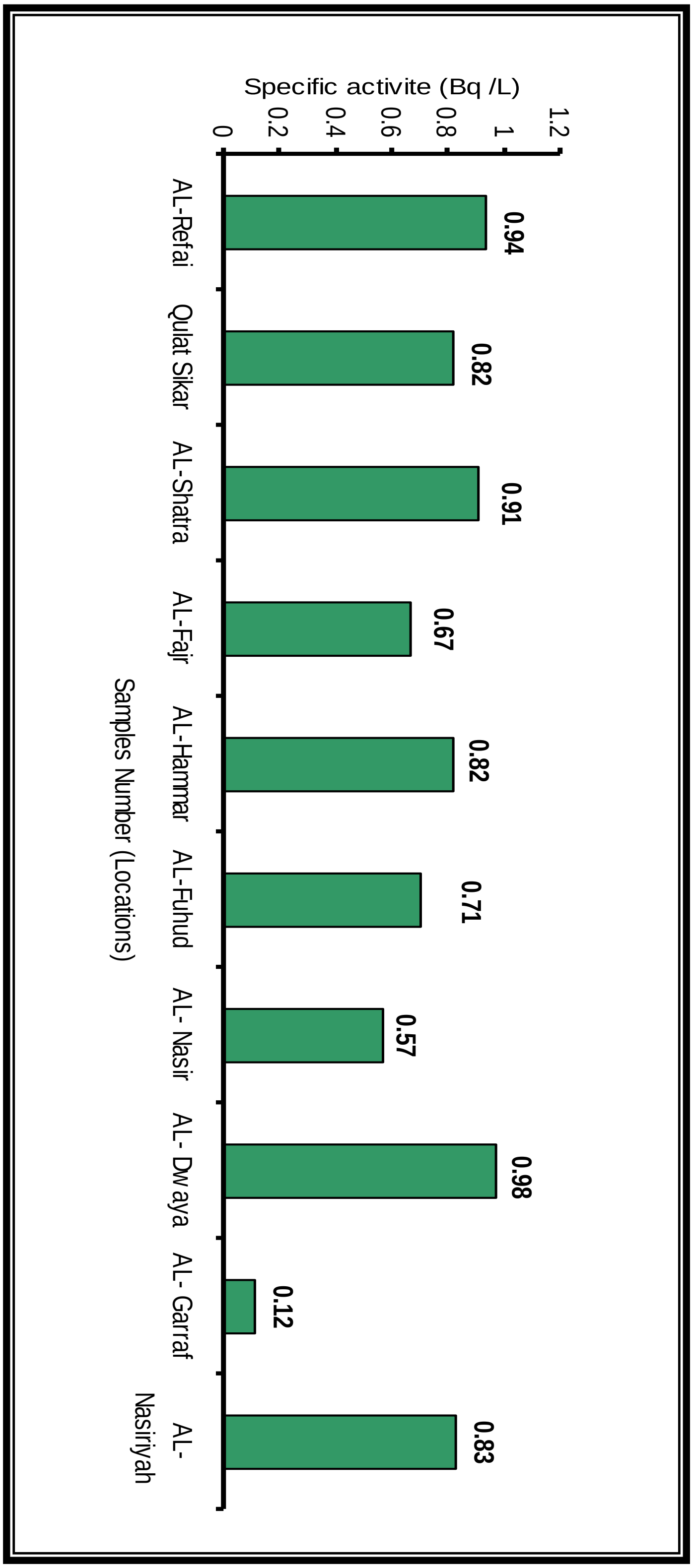

Figure 3. A histogram illustrating the change specific activity concentrations of ^{232}Th for all the regions studied in Thi-Qar governorate.

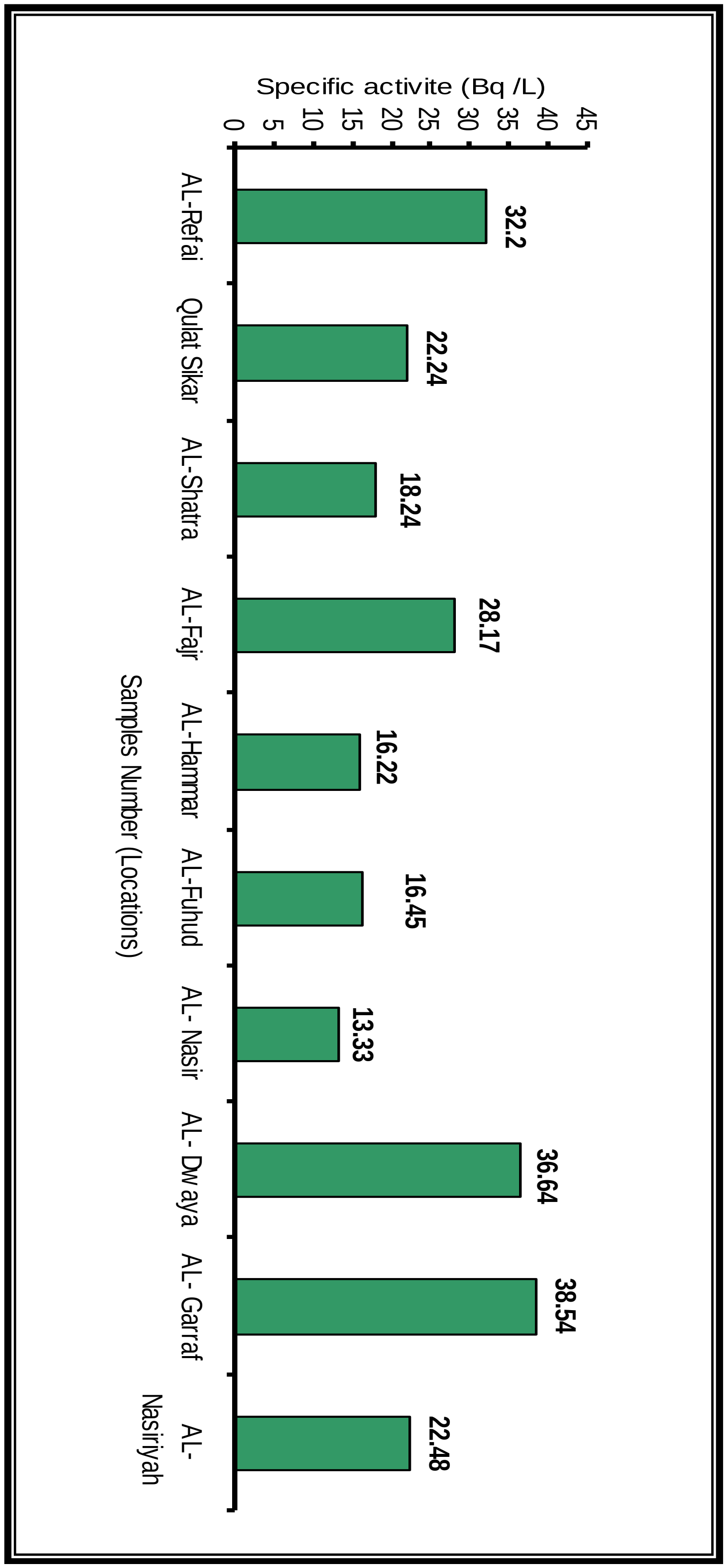

Figure 4. A histogram illustrating the change specific activity concentrations of ^{40}K for all the regions studied in Thi-Qar governorate.