NATURAL RADIOACTIVITY LEVELS IN SOIL SAMPLES OF SOME SCHOOLS IN AL-SHATRAH CITY AT DHI QAR GOVERNORATE, IRAQ

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ABSTRACT In this article, natural radioactivity emitted from ^{238}U, ^{232}Th and ^{40}K were measured in the samples of soil which were gathered from different schools of Al-Shatrah in Dhi Qar Governorate using Gama ray spectroscopy (NaI (Tl), "3×3" volume) technique. The radiation effects resulted from the exposure to radioactivity of the samples under study (e.g. radium equivalent parameter (Ra_{eq}), the absorbed dose rate (D_r), the external hazard (H_{ex}) and the internal hazard (H_{in}) indices, and the representative gamma rays hazard index (I_γ)) were calculated. The annual effective dose (AEDE) together with Excess lifetime cancer risk (ELCR) index were also estimated. The results demonstrated that the averages of the specific activity of the ^{238}U, ^{232}Th and ^{40}K were 10.85±1.34Bq/Kg, 5.81±0.66 Bq/Kg and 354.11±21.60 Bq/Kg, respectively. The average values of each of Ra_{eq}, Dr, H_{ex}, H_{in}, I_γ, $AEDE_{total}$ and ELCR were 46.43±2.94 Bq/kg, 23.29±1.44 nGy/h, 0.125±0.007, 0.154±0.010, 0.366±0.022, 0.142±0.008 mSv/y and (0.499±0.030)×10^{-3} respectively. By comparing the resulted data of this study with that of the average world limits which have been established by UNSCEAR, OCDE and ICRP, one can concluded that there are no health risks threatening the residents of Shatrah due to these radionuclides exist in the soil.

Keywords: natural radioactivity, Gamma ray spectroscopy, soil sample, NaI(Tl), Al-Shatrah, Dhi Qar Governorate

1. INTRODUCTION

It is well known that the 'natural radioactivity' is a major source of exposing humans to radiation. It has a contribution of about 80% of total radiation exposure received by population (Jones et al., 2015). Many types of radiations have been recognized to be emitted in the environment. This includes gamma rays, which are naturally emitted from radionuclides, and are additionally known as terrestrial background. These rays constitute most of the external radiation exposure to human body (L'Annunziata, 2016). For this, the natural radioactivity and the external exposure that is associated with it is mostly because of the gamma rays, which depend entirely on geological and geographical conditions, so their levels are varied completely within the soil in every region of the world. The

background radiation is based on the structural building of the nucleus (Kovler et al., 2017). Earth's radioactive chemicals are called "ground radiation" or "native radionuclides" that can be found in volcanic and sedimentary rocks around the world. Primitive radionuclides include a series of uranium and thorium-produced radionuclides, as well as potassium-40 and rubidium-87 (Kovler et al., 2017). The process of surveillance of the environmental radioactivity level is of considerable importance. This is to ensure the safety and security of society, thus it is necessary to determine the amount of the increment in that level of radioactivity due to its adverse physical and genetic health impacts (Gizewski, 2019). The latter increase in natural radiation is called 'radioactive pollution' which is a portion of the total environmental pollution (Lippmann & Leikauf, 2020). The problem of environmental pollution emerged with the emergence of the industrial era. This is due to the neglect of many countries for the side effects that may result from these industries when designing plans and programs to develop their societies industrially and economically. This neglect includes the health status of workers and the environmental reality surrounding them and their workplaces. The importance of this issue has increased especially with the emergence of the use of nuclear energy as a major and important alternative to the fuel used in energy production, specifically electricity, to supply industry and people with the energy needed to sustain life. Nevertheless, these sources are not free of problems as they are considered as another major source of environmental pollution for most elements of the environment, which are water, air, food and soil (Lippmann & Leikauf, 2020). Soil pollution, as a fundamental concept, depends on information related to the processes of transport and the accumulation pattern away from the place of pollution. This is because the accumulation together with the movement of radioactive materials relies on the interaction between certain materials and compounds with the solid part of the soil. The type of this interaction reflects the ability of the soil to hold radioactive materials. On the other hand, the rate of rainfall and the amount of water irrigation, the type of cultivated plants and soil management processes all are factors that can lead to the movement of radioactive pollutants to the groundwater, or its transmission to plants or other media such as water and air (Engelbrecht, 2020). In this context, there are many studies that have been conducted worldwide to measure the natural radioactivity in soil samples aiming to check pollution levels, (Ribeiro et al., 2018; Günay et al., 2019; Abojassim & Rasheed, 2019 A; Majeed et al., 2019).

Aim of the work: The justification behind investigating the natural radioactivity in the present area is the absence of previous studies that covering these schools, since they have been subjected to military processes together with absence of a radiation map for the province of Dhi Qar Governorate and there is no national number for levels allowed for Iraq, similar to that available in the Arabic world and whole world. Therefore, this study aims to assess the natural radioactivity of each of ^{238}U, ^{232}Th, ^{40}K as well as to assess the radiological impacts (Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ, $AEDE_{total}$ and ELCR) resulted from the exposure to the radioactivity in soil samples collected from different schools of Al-Shatrah city in Dhi Qar Governorate using gamma ray spectroscopy. Finally, it is also intended to establish a natural radioactivity map to be a reference for the future studies using GIS technology.

2. THE STUDY AREA

DhiQar Governorate is one of the elevated Iraqi governorates in the southeastern side of Iraq, DhiQar Governorate is located between the two latitudes (00 ° N 32 ° to the north and '36 30 ° N to the south) and between longitudes (' E '47 ° 12 to East and 'E45 ° 36 to the west) (Jabir, 2008). DhiQar is surrounded by five governorates, Wasit, Qadisiyah in the north, Basra in the south, Maysan in the east, and Muthanna Governorate in the west. Thus, Dhi Qar is the heart of southern Iraq. The population density in this Governorate is considerably high with a population of 1,884,000 people. It is ranked as the fourth governorate among the rest of the governorates of Iraq, after Baghdad, Mosul and Basra, in terms of population. The governorate consisted of five administrative divisions (Jabir, 2008). For example, Nasiriyah, which is the center of the governorate, and covers an area of 1,778,000 donum. The latter is divided into Al-Shatrah, with an area of 725,000 dunams, Souk Al-Shuyukh area of 553,000 donum, Al-Rifai with an area of 1,385,000 donum, and finally, Al Jbaish with an area of 949,000 donum. The current study focuses on measuring the levels of natural radioactivity in soil samples from Al-Shatrah. Al-Shatrah is surrounded by one of the two branches of the Al-Gharraf River that descending from the River of Tigris at the central Euphrates section in south of Iraq. Specifically, it is around 350 km south to the capital of Iraq, Baghdad. It is approximately situated halfway between Baghdad and the Arabic Gulf. This location made Al-Shatrah to occupy a vital geographical part since it has a control over transportation between Baghdad and the Arab Gulf from the one hand and between Baghdad and the rest of the southern cities, on the other and. The study of natural radioactivity in different schools in Al-Shatrah City at Dhi Qar governorate, Iraq was conducted for the first time in this governorate, so it is possible to argue that the current study can be utilized as a baseline to obtain the relevant data or to conduct further research work.

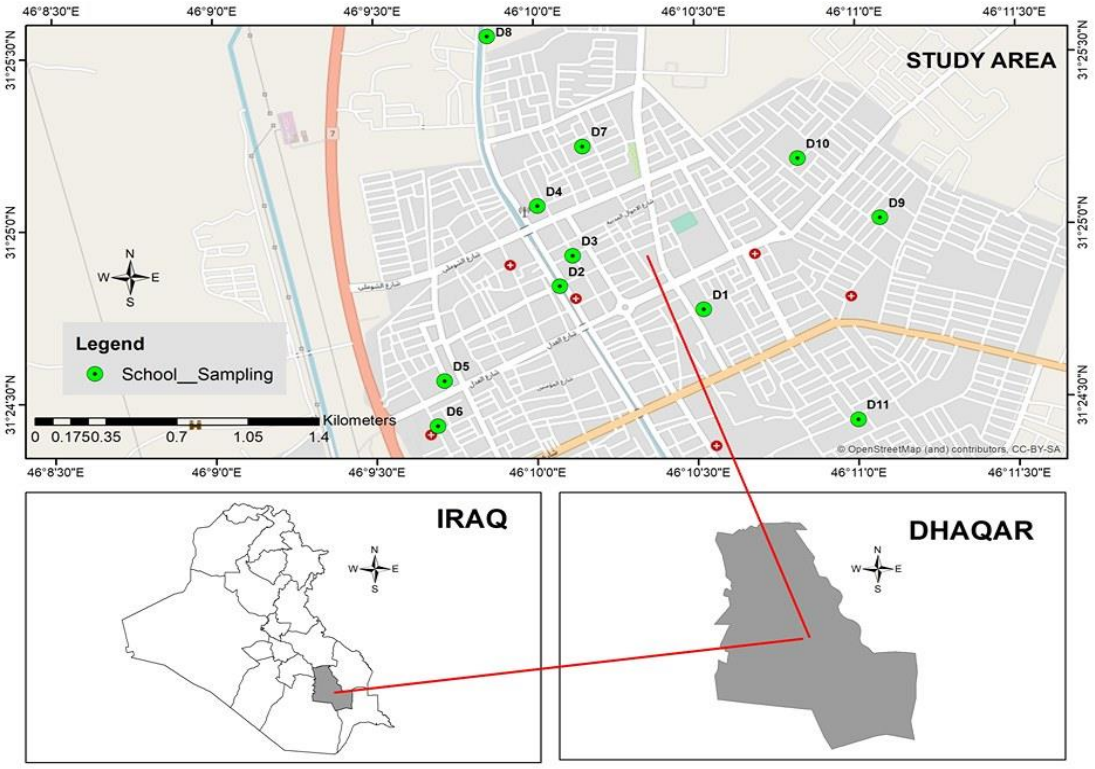

Figure 1. Study area

3. EXPERIMENTAL PROCEDURES

Soil samples at a depth of 15 cm were collected from a number of schools with different locations at Al-Shatrah in DhiQar Governorate. The samples were collected in the spring of 2019. The samples' collection based on the size of the site, and the locations were determined using the GPS technique as can be seen in the Table 1.

Table 1. Coordinate locations for the studied area.

No	Sample code	School name	Coordinates	
			E	N
1	D1	Al-Afa	46.175354	31.412646
2	D2	Al-Shatra for boys	46.167886	31.413806
3	D3	Al-Hekma	46.168572	31.415284
4	D4	Al-Khorouk	46.166768	31.417702
5	D5	Al-Shatra Private	46.161860	31.409297
6	D6	Al-Shatra for girls	46.161481	31.407107
7	D7	Al-Hadbah	46.169149	31.420566
8	D8	Akkad	46.164241	31.425924
9	D9	The martyr Hussein Allawi	46.184546	31.417000
10	D10	Hagar	46.180306	31.419910
11	D11	Yoman	46.183319	31.407252

The samples were transferred to the environmental laboratory which is situated in the Physics department at the faculty of Science at the University of Kufa in order to prepare them for practical measurements. The preparation process includes crushing and cleaning of foreign materials such as cutting stones and gravel and drying them using an electric oven at a temperature of 100 ^{o} C for a period of 4 hours to ensure disposal of any moisture (Abojassim & Rasheed, 2019 A). Then, a sieve with 300μm diameter was used to attain a powder with high homogeneity and then weigh it at 0.75 kg. The samples were packed in plastic cups (marinelli) containing 1 liter polyethylene to obtain the required geometric homogeneity round the detector. A marinelli containers were sealed using a tape then were stored for a month to attain the secular equilibrium between ^{222}Rn and ^{226}Ra in the uranium series. Radiometric measurements were performed using the ORTEC gamma spectroscopy (Part Number 931000) consisting of a NaI(Tl) crystal whose size is (3 × 3), provided by Alpha Spectra, Inc.-12I12 / 3, and a multi-channel analyzer (MCA) that consists of 4096 channels, and also it consists of digital converter (ADC) through energy discrimination (FWHM). At the top, a ^{60}CO source with an energy of 1.33 keV and abundance of 7.9% was used. In order to reduce the effect of different background radiation, a shield that consists of two layers was used, in which the first layer is stainless steel with a width of 10 mm while the second layer is lead with a width of 30 mm (Majeed et al., 2019). The samples were fixed at the center of the shielded container for a period of approximately 5 hours. The radioactivity of ^{40}K, ^{238}U and ^{232}Th was measured using a program (EC & NORTEC). The specific activity of ^{238}U was determined by the energy of l1764.49 keV via the specific activity of ^{214}Bi that having a probability of 15.96%. Concerning the ^{232}Th, the specifica active was determined depending on the energy of 2614 keV via the specific activity of the ^{208}Tl nucleus whose abundance is 99% and ^{40}K was determined via the energy of 1460 keV which is 11% abundance (Abojassim et al., 2020; Sa'ad et al., 2019).

4. RESULTS AND DISCUSSION

Table 2 presents the results of the specific activity for each of ^{238}U, ^{232}Th and ^{40}K in the studied samples of soil. The specific activity can be calculated for the individual sample using the following relation (Al-Hamidawi, 2014; Salman et al., 2018):

$$C\left(Bq/Kg\right) = \frac{C_a}{I \times \varepsilon_{ff} \times M_s} \quad (1)$$

where C refers to the net gamma rate (number of counts per second), ε_{ff} refers to the efficiency of detector, I refers to the gamma ray intensity, M_s sample weight.

The specific activity (Bq/kg) with stander error (S.E) of ^{238}U, ^{232}Th and ^{40}K (Table 2) were ranged from 5.57±0.51 to 22.24±1.05 with an average of 10.85 ± 1.34, from 2.23±0.21 to 8.92±0.40 with an average 5.81± 0.66 and 249.28±3.44 to 453.16±5.98 with an average 354.11±21.60, respectively. The values of the specific activity of the studied samples of the soil were found to be below the global limits according to the UNSCEAR 2000 (i.e. 32 Bq/kg, 30 Bq/kg and 400 Bq/kg for ^{238}U, ^{232}Th and ^{40}K, respectively) (UNSCEAR, 2000), except for the D6, D7, D8 samples in which the Potassium-40 levels were slightly above the permissible limit. Radiological indices (i.e. Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ, AEDE (indoor + outdoor) and ELCR) of the samples can be seen in Tables 3 and 4. The radiological effects were calculated using the following relation:

Radium equivalent (Ra_{eq}) (OECD, 1979; Abojassim & Rasheed, 2019 B):

$$Ra_{eq} = C_{Ra} + (1.43C_{Th}) + (0.077C_K) \quad (2)$$

where C_{Ra}, C_{Th} and C_K specific sample activity in Bq / kg for ^{226}Ra, ^{232}Th and ^{40}K, respectively.

Absorbed dose rate (D_r) (Sa'ad et al., 2019):

$$D_r = \left(nGy/h\right) = DCF_{Ra} \times C_{Ra} + DCF_{Th} \times C_{Th} + DCF_K \times C_K \quad (3)$$

DCF_{Ra} (0.427) and DCF_{Th} (0.662), DCF_K (0.043) dosage conversion factors for ^{226}Ra(^{238}U), ^{232}Th and ^{40}K at nSv/h per Bq/kg (Hasan et al., 2014).

External hazard index (H_{ex}) , internal hazard index (H_{in}) and representative gamma risk index (I_γ) (Abojassim & Rasheed, 2019 B; Hasan et al., 2014) :

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad (4)$$

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (5)$$

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (6)$$

Annual Effective Dose Equivalent (AEDE) (Abojassim et al., 2016; Mirza et al., 2017):

$$AEDE\left(\frac{mSv}{yr}\right) = AEDE_{outdoor} + AEDE_{indoor} \quad (7)$$

$$AEDE_{outdor}(msv/yr) = [D_r(mGy/hr) \times 8766\ hr \times 0.2 \times 0.7Sv/Gy] \times 10^{-6} \quad (8)$$

$$AEDE_{indoor}(mSv/yr) = [D_r(mGy/hr) \times 8766\ hr \times 1.4 \times 0.8 \times 0.7Sv/Gy] \times 10^{-6} \quad (9)$$

where AEDE is the annual effective dose equivalent, AEDE $_{outdoor}$ the effective dose equivalent outside the home, AEDE$_{indoor}$ is the equivalent effective dose inside the home, 0.2 is the occupancy factor in open air, 0.7 Sv / Gy is the dose conversion factor, 8760 is the time of the conversion factor, 1.4 is the ratio of the absolute air Indoor and 0.8 is the indoor occupancy factor.

Excess life-time cancer risk (ELCR) (Al-Hamidawi, 2014; Mirza et al., 2017):

$$ELCR = AEDE \times DL \times RF \quad (10)$$

where, DL represents the average human lifespan, RF represents the risk factor (sv^{-1}) which is equal to (0.055).

According to these tables 3 and 4, it can be seen that the average values of Ra_{eq} , D_r, H_{ex}, H_{in}, I_γ, AEDE and ELCR were 46.43±2.94 Bq/Kg, 23.29±1.44 nGy/h, 0.125±0.007, 0.154±0.010, 0.366±0.022, 0.142±0.008 mSv/y and (0.499±0.030)×10^{-3}, respectively. When comparing the results of aforementioned indices in Tables 3 and 4 with the value of the global level, it was found that the Ra_{eq}, was less than that of the permissible levels of 370 Bq/kg (OECD, 1979), and the absorbed dose rate was less than 55 nGy/h according to UNSCEAR (2000), H_{ex} and H_{in} were still less than one unit according to the report of the Radiation Protection (EC-European Commission, 1999). I_γ was seen to be less than that of the international value (e.g. Iγ <1), whereas the AEDE both in indoor and outdoor and total values were less than that of the corresponding global values of 0.08, 0.42 and 0.50 mSv/y, respectively (ICRP, 1993). Finally, the ELCR values were found to be very low. From the above results, it was found that there are significant differences in the values of specific activity of all samples considered in this study. The reason for this could be due attributed to the geological nature of the studied areas further to the nature of breeding in such locations, namely: sandy and mud. Also, from Table 1, it was found that the specific activity of the uranium was higher than that of thorium across all samples, which is evidenced by uranium average value. Additionally, it can be noticed that the activity of 40K exceeds the noticeable values of both ^{238}U and ^{232}Th, as is the most abundant radioactive element. Finally, the benefit of potassium fertilizers in the sampling sites may contribute to high values of activity ^{40}k.

Table 2. Results of specific activity of ^{238}U, ^{232}Th and ^{40}K for the studied area.

No.	Sample	Specific activity					
		^{238}U (Bq/kg)		^{232}Th (Bq/kg)		^{40}K (Bq/kg)	
		Average	±S.E	Average	± S.E	Average	± S.E
1	D1	22.24	1.05	7.40	0.39	369.75	4.56
2	D2	12.85	0.78	6.89	0.37	273.24	3.82
3	D3	13.15	0.76	6.28	0.34	375.68	4.34
4	D4	8.25	0.58	5.79	0.31	324.28	3.87
5	D5	8.38	0.59	3.41	0.24	249.28	3.44
6	D6	11.39	0.89	8.44	0.49	453.16	5.98
7	D7	11.85	0.83	2.80	0.26	451.86	5.43
8	D8	9.45	0.64	8.92	0.40	421.66	4.57
9	D9	7.19	0.55	6.00	0.32	272.30	3.62
10	D10	9.12	0.68	5.75	0.34	380.32	4.65
11	D11	5.57	0.51	2.23	0.21	323.72	4.10
Average±S.E		**10.85±1.34**		**5.81±0.66**		**354.11±21.60**	
Worldwide average		**32**		**30**		**400**	

Table 3. Results of Ra_{eq}, Dr, H_{ex}, H_{in}, I_{γ} for the studied area.

Sample	**Ra_{eq} (Bq/kg)**	**D_r (nGy/h)**	**H_{ex}**	**H_{in}**	**I_{γ}**
D1	61.293	30.163	0.166	0.226	0.469
D2	43.742	21.492	0.118	0.153	0.337
D3	51.058	25.534	0.138	0.173	0.401
D4	41.499	20.831	0.112	0.134	0.329
D5	32.451	16.326	0.088	0.110	0.256
D6	58.353	29.257	0.158	0.188	0.462
D7	50.647	26.008	0.137	0.169	0.408
D8	54.673	27.337	0.148	0.173	0.433
D9	36.737	18.301	0.099	0.119	0.289
D10	46.627	23.546	0.126	0.151	0.372
D11	33.685	17.419	0.091	0.106	0.275
Average±S.E	**46.43±2.94**	**23.29±1.44**	**0.125±0.007**	**0.154±0.010**	**0.366±0.022**
Worldwide average	**<370**	**55**	**<1**	**<1**	**<1**

Table 4. Results of AEDE and ELCR for the studied area.

Sample	$AEDE_{indoor}$ (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	$AEDE_{total}$ (mSv/y)	ELCR×10^{-3}
D1	0.148	0.037	0.185	0.647
D2	0.105	0.026	0.132	0.461
D3	0.125	0.031	0.157	0.548
D4	0.102	0.026	0.128	0.447
D5	0.080	0.020	0.100	0.350
D6	0.144	0.036	0.179	0.628
D7	0.128	0.032	0.159	0.558
D8	0.134	0.034	0.168	0.587
D9	0.090	0.022	0.112	0.393
D10	0.116	0.029	0.144	0.505
D11	0.085	0.021	0.107	0.374
Average±S.E	**0.114±0.007**	**0.028±0.001**	**0.142±0.008**	**0.499±0.030**
Worldwide average	**0.42**	**0.08**	**0.50**	**–**

For a comparison purposes, the specific activities for uranium-238, thorium-232, and potassium-40 in all the samples are shown in Figures 2 to 4 which is drawn by GIS technology.

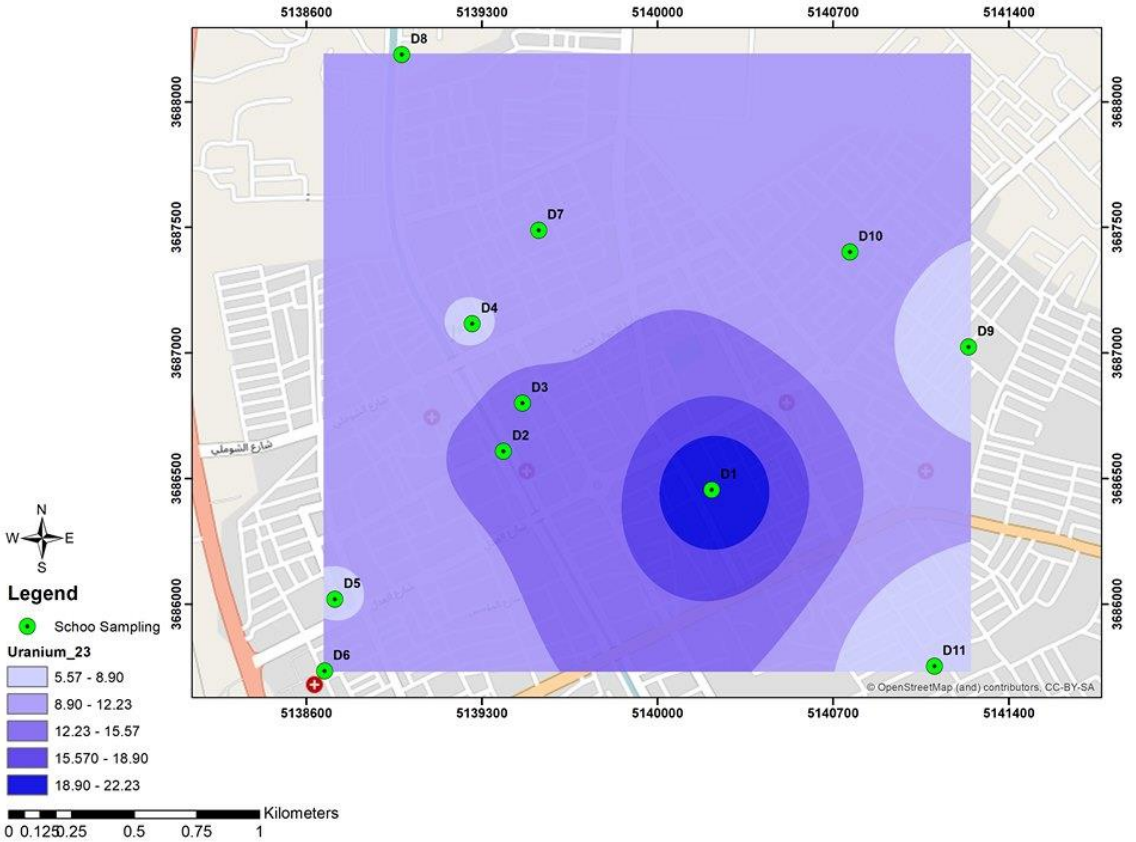

Figure 2. The choropleth maps of the values of the specific activity of ^{238}U in study area.

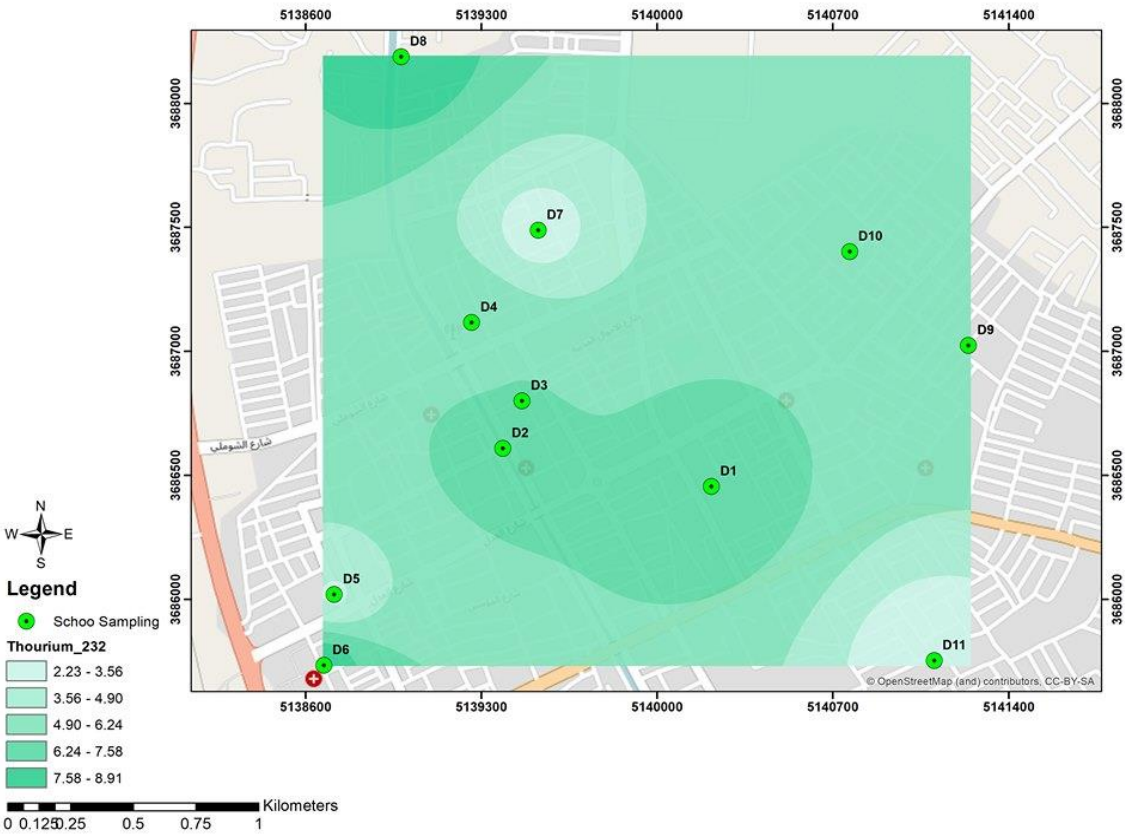

Figure 3. The choropleth maps of the values of the specific activity of ^{232}Th in study area.

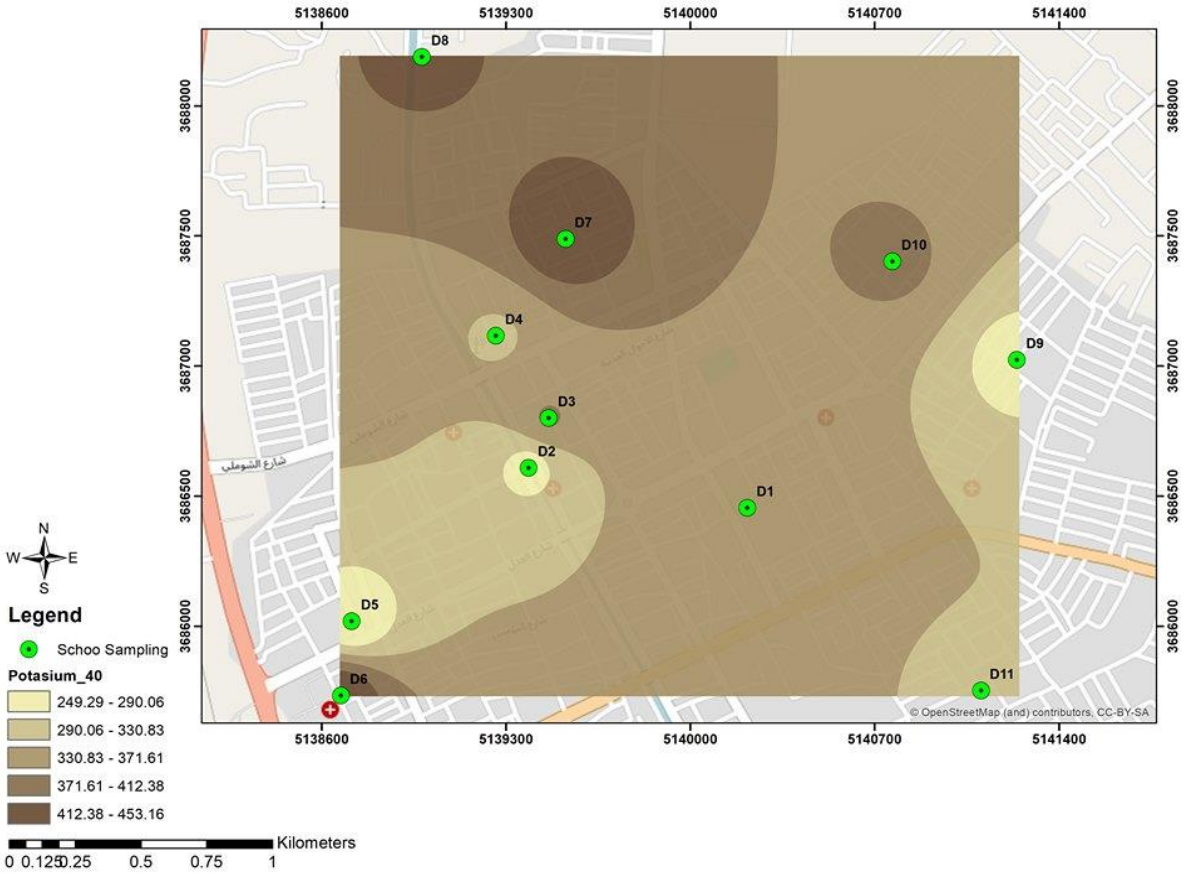

Figure 4. The choropleth maps of the values of the specific activity of ^{40}K in study area.

5. CONCLUSION

The specific activity of each of ^{238}U, ^{232}Th and ^{40}K were lower than the average world values according to UNSCEAR (2000). Also, it was found that majority of the radiation indices (i.e. Ra_{eq}, Dr, H_{ex}, H_{in}, I_{γ}, AEDE and ELCR) were below the world average according to a reports of the UNSCEAR, OCDE and ICRP. In general terms, it can be concluded that the samples under study, are safe for human life because their radioactivity levels are less than the maximum permitted level.

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