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Natural Radioactivity Levels and Heavy Elements Concentration in Soil of Najaf Governorate

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ABSTRACT

Twenty-five soil samples of Najaf provinces, used for the purpose of measuring the radiation pollution and concentration of the elements in the region using γ-ray spectrometry NaI (T_l) detector for the purpose of measuring the concentration of natural radionuclides of 238U, 232Th, 235U and 40K, found the activity of 238U (0.027±0.023 to 27.913±0.871 Bq/kg), (4.5751±0.447 to 31.753±0.745 Bq/kg) for 232Th, (44.731±1.275 to 368.768±3.663 Bq/kg) for 40K and from 0.001±0.007 to 1.286±0.243 for 235U. The radiological hazards due to natural radionuclides content calculated such as gamma dose rate (AD), radium equivalent activity and annual effective dose equivalent (AEDE) ranged between 0.4498 to 0.121 Bq/kg. Also X-Ray Fluorescent (XRF) spectrometer was used to determine natural elements. The results of the present work concerning values of the specific activity concentrations for ^{238}U, ^{232}Th and ^{40}K, and the parameters (radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose equivalent, external annual effective dose, the gamma index, internal and external hazard indicies), all were found to be lower than their corresponding allowed values given by UNSCEAR and hence will pose relatively none serious health risk. The results were then inserted into the computer memory and converted to digital data. The Gis 10.4 program was used to produce radio maps of the governorate of Najaf.

Key words : Heavy material , X-Ray Fluorescent (XRF), natural radioactivity

INTRODUCTION

The natural radioactivity in the environment is the main source of radiation exposure for human body. Natural radionuclide in soil contributes a significant amount of background radiation exposure to the population through inhalation and ingestion. The main contributors of radionuclides are ^{226}Ra, ^{232}Th and ^{40}K. Since these radionuclides in soils are not uniformly distributed and vary from region to region (Dizman e*t al.,* 2016). Therefore, the knowledge of their distribution in soil and rock plays an important role in radiation protection and measurement. The radioactivity concentration of these nuclides above permissible level is very harmful to the human body. Therefore, measurements of natural radioactivity in soils and the radiation doses are of great interest to the researchers which have led the nationwide surveys throughout the world. There have been many surveys to determine the background levels of radionuclides in soils which have been turned out to calculate the absorbed dose in air (Kadhim and Muttaleb, 2016).

Internal exposure occurs through inhalation of radon gas and external exposure occurs through the emission of penetrating gamma rays. Environmental natural gamma background radiation varies with geological and geographical structure and dominates external radiation dose to human body. Studies of natural radioactivity are necessary not only because of their radiological impact but also because they act as excellent biochemical and geochemical tracers in the environment (Durusoy and Yildirim, 2017).

The aim of the present work was to search the possibility of uranium deposition as ore and health risk assessment associated with thorium and potassium in the study area. This work was undertaken to measure the activity concentrations and γ-ray absorbed doses of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) in soil samples; another aim of the present work was to create the public awareness about the radiation hazards and the workers those who are working in this tea garden. This study will also be helpful to establish a research base line in this area.

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MATERIALS AND METHODS

The governorate of Najaf is located coordinates : 32°00′00″N, 44°20′00″E in south-western Iraq and borders Saudi-Arabia. Najaf also shares internal boundaries with the governorates of Anbar, Karbala, Babil and Qadissiya. Desert plains dominate the landscape of the governorate. A ribbon of irrigated farm land runs along the course of the Euphrates River, which intersects the governorate near its eastern border. Samples were collected from the two governorates in a manner in which each administrative governorate was divided into a research that was sufficient to include the districts of each governorate. The samples were carefully selected away from the cultivated soil and agricultural areas.

The soil samples collected from 25 locations at a depth of 15 cm, about 1.00 kg were neatly packed in well-labelled polyethylene bags properly sealed and transported to the radiation laboratory that were sifted and removed the impurities and then dried samples and stored for 30 days before counting to allow secular equilibrium to be attained between ^{222}Rn and its parent ^{226}Ra in uranium chain before measurement using a gamma spectrometry system.

Activity concentrations of the natural radionuclides of ^{232}Th, ^{238}U, ^{40}K and ^{235}U were measured using NaI (T_l) γ-ray spectrometer of (3"×3") crystal dimension, supplied by Alpha Spectra, Inc.-12I12/3, coupled with a multi-channel analyzer (MCA) ORTEC-Digi Base with range of 4096 channel joined with ADC (Analog to Digital Convertor) unit, through interface, the spectral data were converted directly to the PC of the laboratory introduced using (Maestro-32) software. Measurements were made to check the background level of radioactivity in the laboratory the γ-ray photo peaks corresponding to 11747ev of ^{40}K, 2503ev for ^{238}U and 662ev of ^{232}Th. The calibration of the detector enabled us to find the linear relationship between the pulse coming out of the detector and the gamma energy falling on the crystallization of the detector. The relationship between the channel number in the multichannel analyzer and the spectral line energy of the studied isotopes. The MCD consisted mainly of memory with storage locations equal to the number of MCD channels where the pulses were stored in these channels according to the energy of each pulse. The pulses that had the same energy were stored in the same channel. The program used in processing the data allowed to represent the number of pulses according to the sequence of the channel. It was possible to deduce the channel number associated with the known isotope energy (Arafat *et al.,* 2017). Activity concentrations of samples were determined by the net area under the photo peaks and calculated by Arafat *et al.* (2017).

$$A=Cnet/(\varepsilon.I\gamma\ m.t)+\sqrt{(Cnet)}/(\varepsilon.I\gamma\ m.t) \quad ...(1)$$

Where, C_{net} : the net count, ε : efficiency of detector, t : time for spectrum, m : weight of the samples in kg. Iγ the transition probability of the emitted gamma ray. The results are tabulated in Table 2 (soil) Table 3 (rocks).

The radium equivalent activity given by the relation (Karim *et al.*, 2016) :

$$Ra–eq(Bq/kg)=Au+1.43\ ATh+0.077\ 40K \quad ...(2)$$

This radium equivalent activity defined the weighted sum of the individual activities of ^{40}K,^{238}U and ^{232}Th.

The absorbed dose rates (D_R) were calculated in air from the activity concentrations of ^{238}U, ^{232}Th and ^{40}K concentrations in soil. The total dose rate in the air at 1 m above the ground surface due to uniform distribution of all the ^{238}U, ^{232}Th and ^{40}K in each soil was calculated by equation :

$$DR\left(\frac{nGy}{h}\right)=0.462AU+0.621ATh+0.0417AK \quad ...(3)$$

Where, D_R : is the dose rate , A_U, A_{Th} and A_k are the concentration of uranium, thorium and potassium. It reflects the dose received by a person from outdoor radionuclides, the first step to estimate the health risks of radiation. The results of samples from the soil of the area under the study obtained are reported in Table 1.

The annual effective dose rate equivalent was calculated using a conversion factor of 07 $SvGy^{-1}$ to convert the absorbed dose rate to the effective dose equivalent and 0.2 for the outdoor occupancy factor (Manavhela, 2007).

(AEDE) outdoor=D_R (nGh^{-1}) x 8760 ($h.y^{-1}$) x 0.7 x (10^3mSv/nGy10^9) x 0.2

(AEDE) outdoor=D_R x (1.226 x 10^{-3}mSv.y^{-1}) ...(4)
(AEDE) indoor=D_R (nGh^{-1}) x 8760 (h.y^{-1}) x 0.7 x (10^3mSv/nGy10^9) x 0.8
(AEDE) outdoor=D_R x (1.226 x 10^{-3}mSv.y^{-1}) ...(5)
The result of the absorbed dose rate (AEDE) is given in Table 1.
The external hazard index was obtained from (Ra_{eq}) expression through the supposition that it allowed maximum value (equal to unity) corresponding to the upper limit of Raeq (370 Bq/kg). The external hazard index (H_{ex}) can then be defined as (Ismail and Jaafar, 2010) :

$$Hex=AU/370+ATh/259+AK/4810\leq 1 \quad ...(6)$$

Another factor depend on the activity concentrations of the three radionuclides ^{238}U, ^{232}Th and ^{40}K called the representative level index (Iγ) defined by the following equation (Hassan *et al.,* 2011; Al-Hamidawi *et al.,* 2012) :

$$Iy=1/150\ AU+1/100ATh+1/1500Ak \quad ...(7)$$

It is possible to calculate the internal exposure to radon resulting from alpha rays, which causes cancer, through which to know the short life span of the series; and it is given below (Nisha *et al.,* 2014; Kaur *et al.,* 2015) :

$$Hin=AU/185+ATh/259+AK/4810\leq 1 \quad ...(8)$$

RESULTS AND DISCUSSION

In soil samples, the activity concentrations were found in the range of ^{238}U (0.027±0.023 to 27.913±0.871 Bq/kg), 4.5751±0.447 to 31.753±0.745 Bq/kg for ^{232}Th, 44.731±1.275 to 368.768±3.663 Bq/kg for ^{40}K and from 0.001±0.007 to 1.286±0.243 Bq/kg for ^{235}U (Table 1). Figs. 1, 2 and 3 represent the geographical distribution of radioisotopes ^{238}U, ^{232}Th and ^{40}K in Najaf governorate. Fig. 1 represents ^{238}U in study area and notes that the highest concentrations were in the rock area. Fig. 3 contains distribution map of ^{40}K in Najaf governorate where there was the highest concentration in residential and agricultural areas, while the lowest concentration in the rock area. Fig. 2 represents geomorphic distribution of the thorium, the figure shows

Table 1. Activity concentration of natural radionuclides (Bq/kg) in soil

No.	S. C.	Activity concentration (Bq/kg)			
		^{238}U	^{232}Th	^{40}K	^{235}U
1.	N_1	7.788±0.460	11.628±0.565	255.102±3.047	0.358±0.128
2.	N_2	11.356±0.556	15.196±0.308	296.449±3.284	0.523±0.155
3.	N_3	0.953±0.161	4.793±0.145	160.471± 2.416	0.043±0.044
4.	N_4	12.282±0.578	16.122±0.471	332.336± 3.477	0.565±0.161
5.	N_5	25.490±0.833	29.330±0.527	275.339± 3.165	1.174±0.232
6.	N_6	25.517± 0.833	29.357±0.582	339.578±3.515	1.175±0.232
7.	N_7	1.933± 0.229	5.773 ±0.353	338.741±3.511	0.089±0.064
8.	N_8	9.831± 0.517	13.671±0.609	368.768±3.663	0.453±0.144
9.	N_9	25.871±0.839	29.711±0.474	250.589±3.020	1.192±0.234
10.	N_{10}	13.099± 0.597	16.938±0.310	265.730±3.109	0.603±0.166
11.	N_{11}	2.559±0.264	6.399±0.794	44.731±1.275	0.117±0.073
12.	N_{12}	27.913± 0.871	31.753±0.745	357.522±3.607	1.286±0.243
13.	N_{13}	7.434±0.449	11.274±0.102	247.204±2.999	0.342±0.125
14.	N_{14}	0.735±0.141	4.5751±0.447	316.758±3.395	0.033±0.039
15.	N_{15}	9.286±0.502	13.126±0.469	265.948±3.111	0.427±0.140
16.	N_{16}	0.027±0.027	3.867±0.710	210.662±2.769	0.001±0.007
17.	N_{17}	21.023±0.756	24.863±0.403	250.407±3.018	0.968±0.211
18.	N_{18}	10.784±0.541	14.624±0.440	204.184±2.726	0.496±0.151
19.	N_{19}	12.254 ±0.577	16.094±0.243	208.879± 2.757	0.564±0.161
20.	N_{20}	25.708± 0.836	29.547±0.443	210.407±2.767	1.184±0.233
21.	N_{21}	15.114 ±0.641	18.954±0.565	284.219±3.216	0.696±0.179
22.	N_{22}	3.267±0.298	7.107±0.150	281.344±3.199	0.150±0.083
23.	N_{23}	21.023±0.756	24.863± 0.335	271.481±3.143	0.968±0.211
24.	N_{24}	18.001±0.700	21.840± 0.647	283.873±3.737	0.829±0.195
25.	N_{25}	7.461±0.450	11.301 ± 0.433	255.678±3.063	0.343± 0.125
Max.		27.913± 0.871	31.753±0.745	368.768±3.663	1.286±0.243
Min.		0.027±0.023	4.5751±0.447	44.731±1.275	0.001±0.007
Ave.		12.668	16.508	263.056	0.583
Global range UNSCEAR (2016)		35	30	400	-

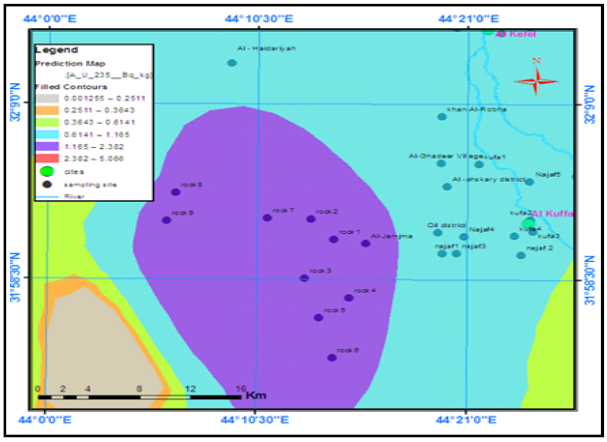

Fig. 1. The distribution of uranium U-235 in soil and rocks in study area.

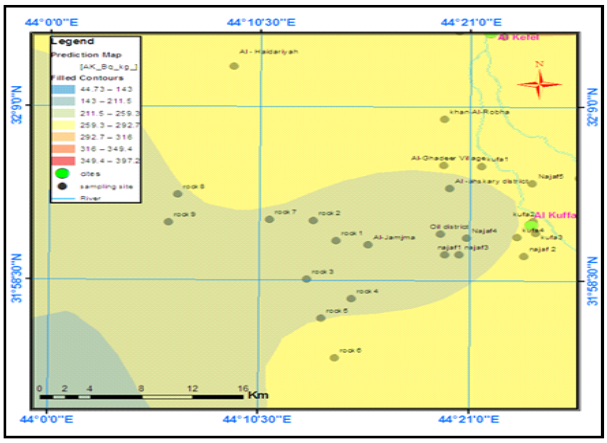

Fig. 2. The distribution of thorium Th-232 in soil and rocks in study area.

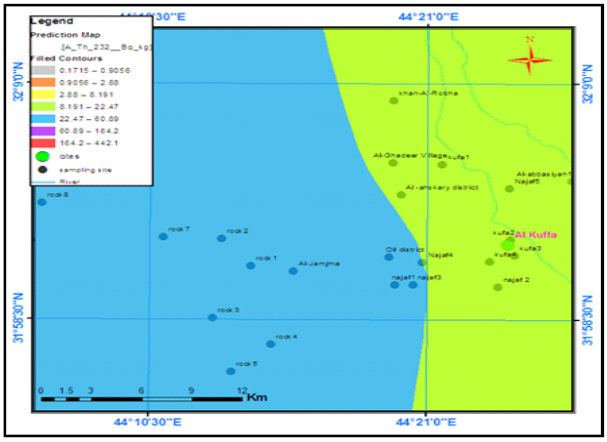

Fig. 3. The distribution of potassium K-40 in soil and rocks in study area.

that the highest concentration of thorium covered large areas of the province and evidenced that thorium concentration was predominant in the study area. In order to assess the health effects, the radiation hazards such as absorbed dose rate (DR), effective dose rates (E), radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) had been calculated from the activity of nuclides ^{238}U, ^{232}Th and ^{40}K using the equations 3, 2 and 6, respectively, and the values have been shown in Tables 2 and 3. From Table 2, the radium equivalents activity (Ra_{eq}) was found in the range of 14.719±1.380 to 92.645±2.409 Bq/kg with an average value of 47.760 Bq/kg. The average value of the radium equivalent was less than the safe limits as recommended by the organization for economic cooperation and development (ECD). Any Ra_{eq} concentration value that exceeds 370 Bq/kg may pose radiation hazards. Outdoor air absorbed dose rate due to terrestrial gamma rays at 1 m above the ground was calculated by equation (4) for ^{332}Th ^{238}U and ^{40}K and the range was 6.814±0.658 to 46.099±1.063 $nGyh^{-1}$ with an average of 26.387 $nGyh^{-1}$.

The values of D_R for all soil samples of the archaeological of Najaf city were under limit, the global limit value (55 nGy/h). The annual effective dose rate equivalent (AEDE-outdoor) and (AED-indoor) was calculated using equations (4) and (5), a conversion factor of 0.7 $SvGy^{-1}$ to convert the absorbed dose rate from the effective dose equivalent and 0.2 for the outdoor occupancy factor. Results are tabulated in Tables 2 and 3.

The total annual effective dose rates were found in the range of 0.072±0.004 to 0.495±0.006 $mSvy^{-1}$ with an average value of 0.283 $mSvy^{-1}$ which was also less than the world average of 1 mSv/y.

The value of (Iγ) calculated by equation (7) ranged between 0.383±0.010 to 050.0±05000 with the average value of 0.203. The present results showed that values of Iγ for soil samples of the archaeological of Najaf city were less than the recommended value of 1 for the Iγ given by UNSCEAR 2016. The values of Hin and Hex ranged between 0.347±0.009 to 0.047±0.005 and from 0.272±0.006 to 0.040±0.004, respectively, with the average value of 0.187 and 0.152, respectively. It can be seen that all the soil samples of the archaeological of Najaf city were less than the recommended value of 1 for Hin and Hex given by mutual relationships and the level of association that may exist among the calculated radiological variables were assessed through the calculation of Pearson's correlation coefficients. The results of

Table 2. Absorbed dose rate (AD) indoor and outdoor (nGy/h), Annual effective dose (AEDE) indoor, outdoor and total dose ($mSvy^{-1}$) in Najaf city (soil)

S. No.	S. C.	Ra_{eq}	Absorbed dose rate (AD)		Annual effective dose equivalent (AEDE)	
			$AD_{outdoor}$	AD_{indoor}	$AEDE_{outdoor}$	$AEDE_{indoor}$
1.	N_1	48.733±1.885	20.999±0.818	40.620±0.789	0.025±0.001	0.199±0.004
2.	N_2	40.527±2.032	26.415±0.881	51.175±0.880	0.032±0.001	0.251±0.004
3.	N_3	14.719±1.380	9.978±0.599	19.147±0.510	0.012±0.0009	0.093±0.003
4.	N_4	52.706 ±2.068	28.870±0.896	55.952±0.907	0.035±0.001	0.274±0.004
5.	N_5	65.234±2.401	40.164±1.038	78.016±1.107	0.049±0.001	0.382±0.005
6.	N_6	74.284±2.409	42.871±1.042	83.274±1.122	0.052±0.001	0.408±0.005
7.	N_7	36.353±1.523	18.426±0.664	35.567±0.613	0.022±0.0009	0.174±0.003
8.	N_8	63.022±1.983	27.852±0.861	53.953±0.863	0.034±0.001	0.264±0.004
9.	N_9	60.215±2.406	39.526±1.040	76.781±1.106	0.048±0.001	0.376±0.005
10.	N_{10}	39.996±2.087	26.938±0.904	52.208±0.907	0.033±0.001	0.256±0.004
11.	N_{11}	48.147±1.524	6.814±0.658	13.018±0.549	0.008±0.0009	0.063±0.003
12.	N_{12}	92.529±2.458	46.099±1.063	89.569±1.158	0.056±0.001	0.439±0.005
13.	N_{13}	74.284±1.868	20.303±0.810	39.265±0.778	0.024±0.001	0.192±0.004
14.	N_{14}	27.174±1.367	16.269±0.596	31.366±0.534	0.019±0.009	0.153±0.003
15.	N_{15}	38.489±1.950	23.001±0.845	44.524±0.828	0.028±0.001	0.218±0.004
16.	N_{16}	44.476±1.107	11.112±0.482	21.342±0.392	0.013±0.0008	0.104±0.003
17.	N_{17}	49.963±2.300	34.501±0.995	66.975±1.037	0.042±0.001	0.328±0.004
18.	N_{18}	51.186±1.999	21.976±0.865	42.547±0.845	0.026±0.001	0.208±0.004
19.	N_{19}	39.440±2.051	23.694±0.888	45.897±0.876	0.029±0.001	0.225±0.004
20.	N_{20}	32.292±2.397	37.681±1.035	73.197±1.094	0.046±0.001	0.359±0.005
21.	N_{21}	41.174±2.151	29.795±0.931	57.776±0.949	0.036±0.001	0.283±0.004
22.	N_{22}	54.408±1.632	17.414±0.710	33.614±0.658	0.021±0.001	0.164±0.003
23.	N_{23}	26.433±2.303	35.380±0.996	68.682±1.043	0.043±0.001	0.336±0.005
24.	N_{24}	43.939±2.241	32.768±0.971	63.579±1.020	0.040±0.001	0.311±0.004
25.	N_{25}	43.923±1.885	20.684±0.811	40.006±0.781	0.025±0.001	0.196±0.004
Max.		92.645±2.409	46.099±1.063	89.569±1.158	0.056±0.001	0.439±0.005
Min.		14.719±1.380	6.814±0.658	3.018±0.549	0.008357774	0.063±0.003
Ave.		47.760	26.387	51.135	0.032	0.250
Global range	UNSCEAR (2016)	370	55	55	1	1

Table 3. The hazard index (external H_{ex} and internal H_{in}) activity index (Iγ) in soil of Najaf governorate

S. No.	S. C.	$AEDE_{Total}$	H_{ex}	H_{in}	Iγ
1.	N_1	0.225±0.005	0.118±0.005	0.140±0.006	0.149±0.005
2.	N_2	0.283±0.005	0.150±0.005	0.181±0.007	0.196±0.006
3.	N_3	0.106±0.004	0.054 ±0.003	0.057±0.004	0.058±0.002
4.	N_4	0.309±0.005	0.164±0.005	0.197±0.007	0.213±0.007
5.	N_5	0.431±0.006	0.239±0.006	0.308±0.008	0.340±0.009
6.	N_6	0.461±0.006	0.252±0.006	0.321±0.008	0.354±0.009
7.	N_7	0.197±0.004	0.097±0.004	0.103±0.005	0.105±0.003
8.	N_8	0.298±0.005	0.156±0.005	0.182±0.007	0.194±0.006
9.	N_9	0.425±0.006	0.236±0.006	0.306±0.008	0.339±0.009
10.	N_{10}	0.289±0.005	0.156±0.005	0.191±0.007	0.207±0.007
11.	N_{11}	0.072±0.004	0.040±0.004	0.047±0.005	0.051±0.003
12.	N_{12}	0.495±0.006	0.272±0.006	0.347±0.009	0.383±0.010
13.	N_{13}	0.217±0.005	0.115±0.005	0.135±0.006	0.144±0.005
14.	N_{14}	0.173±0.004	0.085±0.003	0.087±0.004	0.088±0.003
15.	N_{15}	0.246±0.005	0.131±0.005	0.156±0.007	0.167±0.006
16.	N_{16}	0.118±0.003	0.058±0.002	0.058±0.003	0.058±0.002
17.	N_{17}	0.370±0.006	0.204±0.006	0.261±0.008	0.288±0.008
18.	N_{18}	0.235±0.005	0.128±0.005	0.157±0.007	0.170±0.006
19.	N_{19}	0.254±0.005	0.138±0.005	0.171±0.007	0.187±0.006
20.	N_{20}	0.405±0.006	0.227±0.006	0.296±0.008	0.329±0.009
21.	N_{21}	0.319±0.005	0.173±0.005	0.213±0.007	0.233±0.007
22.	N_{22}	0.186±0.005	0.094±0.004	0.103±0.005	0.107±0.004
23.	N_{23}	0.380±0.006	0.209±0.006	0.266±0.008	0.292±0.008
24.	N_{24}	0.352±0.006	0.191±0.006	0.240±0.008	0.263±0.008
25.	N_{25}	0.221±0.005	0.116±0.005	0.137±0.006	0.146±0.005
Max.		0.495±0.006	0.272±0.006	0.347±0.009	0.383±0.010
Min.		0.072 ±0.004	0.040±0.004	0.047±0.005	0.051±0.003
Ave.		0.283	0.152	0.187	0.203
Global range	UNSCEAR (2016)	1	1	1	1

Table 4. Pearson's correlation matrix of radioactivity and heavy elements

	AK	(U-238)	(U-235)	(Th-232)	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Zr	M0	W	Au	Hg	Pb	Th	U
AK	1	0.286	0.286	0.286	-0.0509	-0.096	-0.016	-0.089	-0.02	-0.191	-0.2	-0.36	-0.226	-0.42	-0.19	-0.09	0.0256	0.288	-0.764	0.685	0.211	0.0264
A (U-238)	0.286	1	1	1	25	25	-0.068	-0.111	0.026	-0.199	0.128	0.103	-0.239	-0.37	0.584	0.046	0.0446	-0.33	-0.282	0.333	0.435	0.4196
A (U-235)	0.286	1	1	1	-0.0027	0.154	-0.068	-0.111	0.026	-0.199	0.128	0.103	-0.239	-0.37	0.584	0.046	0.0446	-0.33	-0.282	0.333	0.435	0.4196
A (Th-232)	0.286	1	1	1	-0.0027	0.154	-0.068	-0.111	0.026	-0.199	0.128	0.103	-0.239	-0.37	0.584	0.046	0.0446	-0.33	-0.282	0.333	0.435	0.4196
Mn	-0.051	-0.003	-0.0033	-0.003	1	-0.929	0.9638	0.8341	0.731	0.555	0.687	0.585	0.9107	-0.38	0.568	-0.116	0.6187	-0.24	0.243	0.035	0.143	-0.307
Fe	-0.096	0.154	0.154	0.154	-0.9291	1	-0.921	-0.825	-0.72	-0.541	-0.57	-0.53	-0.862	0.447	-0.35	0.157	-0.586	0.096	-0.118	-0.04	-0.087	0.2976
Co	-0.016	0.068	-0.068	-0.068	0.96376	-0.921	1	0.8754	0.752	0.681	0.565	0.517	0.9447	-0.38	0.507	-0.287	0.706	-0.32	0.262	0.047	0.063	-0.302
Ni	-0.089	-0.111	-0.111	-0.111	0.83407	-0.825	0.8754	1	0.722	0.652	0.683	0.675	0.7952	-0.1	0.44	-0.133	0.8483	-0.2	0.4024	-0.14	0.006	-0.408
Cu	-0.021	0.0256	0.0256	0.026	0.73143	-0.723	0.7515	0.722	1	0.71	0.57	0.661	0.6122	-0.13	0.544	0.045	0.6361	-0.29	0.3043	0.267	-0.066	-0.045
Zn	-0.191	-0.199	-0.199	-0.199	0.55526	-0.541	0.6811	0.6524	0.71	1	0.333	0.313	0.6475	-0.01	0.202	-0.41	0.7854	-0.39	0.3553	0.174	-0.129	-0.1
As	-0.196	0.128	0.128	0.128	0.68737	-0.574	0.5652	0.6828	0.57	0.333	1	0.8	0.4798	0.201	0.517	0.473	0.5269	-0.1	0.4639	0.019	0.051	-0.522
Se	-0.359	0.1082	0.1032	0.103	0.58496	-0.532	0.5166	0.6748	0.661	0.313	0.8	1	0.484	0.091	0.649	0.367	0.3965	-0.36	0.5616	-0.24	0.108	-0.244
Rb	-0.226	-0.239	-0.239	-0.239	0.9107	-0.862	0.9447	0.7952	0.612	0.648	0.48	0.484	1	-0.34	0.432	-0.372	0.579	-0.39	0.3285	-0.13	0.117	-0.328
Sr	-0.421	-0.366	-0.366	-0.366	-0.378	0.447	-0.379	-0.102	-0.13	-0.013	0.201	0.091	-0.344	1	-0.27	0.541	-0.013	0.172	0.5241	-0.09	-0.468	-0.476
Zr	-0.188	0.5838	0.5838	0.584	0.56849	-0.346	0.5074	0.4405	0.544	0.202	0.517	0.649	0.4319	-0.27	1	0.027	0.3568	-0.66	0.3882	-0.04	0.193	0.1829
M0	-0.09	0.0456	0.0456	0.046	-0.1156	0.1566	-0.287	-0.133	0.045	-0.41	0.473	0.367	-0.372	0.541	0.027	1	-0.316	0.402	0.1829	0.067	-0.172	-0.323
W	0.0256	0.0446	0.0446	0.045	0.61867	-0.586	0.706	0.8483	0.636	0.785	0.527	0.396	-0.579	-0.01	0.357	-0.316	1	-0.26	0.3387	0.093	-0.091	-0.226
Au	0.2879	-0.328	-0.328	-0.328	-0.2383	0.0965	-0.323	-0.198	-0.29	-0.393	-0.1	-0.36	-0.388	0.172	-0.66	0.402	-0.259	1	-0.431	0.029	-0.093	-0.196
Hg	-0.764	-0.282	-0.282	-0.282	0.24304	-0.118	0.262	0.4024	0.304	0.355	0.464	0.562	0.03285	0.524	0.388	0.183	0.3387	-0.43	1	-0.49	-0.562	-0.273
Pb	0.6846	0.3327	0.3327	0.333	0.03475	-0.043	0.0469	-0.139	0.267	0.174	0.019	-0.24	-0.126	-0.09	-0.04	0.057	0.0931	0.029	-0.493	1	0.131	-0.031
Th	0.211	0.4346	0.4346	0.435	0.14283	-0.087	0.063	0.0059	-0.07	-0.129	0.051	0.108	0.1166	-0.47	0.193	-0.172	-0.091	-0.09	-0.562	0.131	1	0.1421
U	0.0264	0.4196	0.4196	0.42	-0.3075	0.2976	-0.302	-0.408	-0.05	-0.1	-0.52	-0.24	-0.328	-0.48	0.183	-0.323	-0.226	-0.2	-0.273	-0.03	0.142	1

correlation matrix among the radiological variables for the tailing enriched soil samples are presented in Table 4. The results showed a very high positive relationship r2=1 between 235U and 238U. This relationship was expected owing to the fact that 235U and 238U decay series had common origin and existence in nature (28, 38). Furthermore, the measured radiological variables showed very strong (r^2 = 1) positive correlation with one another and with the primordial radionuclides between 238U and 232Th; negative relationship between 40K and all heavy elements except pb high positive. 238U positive relationship with pb, Se but negative with Co, Ni, Zn, Sr, while negative relation between Fe, As, Se, Hg and with isotopes.

CONCLUSION

The observed environmental radiation using sodium iodide NaI (T_l) detector showed distribution of the natural radiation levels in all the samples of the archaeological of Najaf city. The highest concentrations of the two isotopes 238^{U} and 232^{Th}, the region of Najaf sea, artificial radionuclide was not detected in any of the measured samples, the average specific activity of 238U, 232Th and K was found that recommended values given by UNSCAIR, report and accepted with the radiation levels were within the permissible limits, and the radioactive hazard was low for human-beings (employees or tourists) in this area. The correlation analysis between heavy metals and natural radionuclides in top soil suggested that the heavy metals like Pb, As, Zn, Cu, Cr and Co may not be responsible for increasing natural radioactivity level of 238U and 232Th in topsoil of the study area but radioactivity level of 40K may arise from clay minerals and/or agricultural inputs in this area.

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