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CALCULATION OF RADIOLOGICAL HAZARD FOR SOIL SAMPLES COLLECTED FROM RIGHT COAST OF NINEVEH-IRAQ

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ABSTRACT

In the current study, the activity of 20 soil samples collected from five schools in Nineveh, Iraq has been investigated. The Sodium iodide detector NaI (Tl) was used to calculate the concentration of ^{226}Ra, ^{232}Th and ^{40}K. The average concentration of ^{226}Ra, ^{232}Th and ^{40}K (ppm) has been found to be 1.53, 1.32 and 3.02% respectively. Radiological hazard of representative level index (RLI), activity utilization index (AUI), concentration index I_C, Alpha index ($I_á$), annual effective dose (AEDE), excess life-time cancer risk (ELCR) have been estimated. From results, the radiological hazards have been lower than permeation level recommended by UNSCEAR. On the other side, the ELCR was being 1.2819*10^{-3}, it was below internationally recommended limits by UNSCEAR. Radiological hazard were statistically measured to get the relation between all the parameters. The Pearson correlation (PC) and statistically significant (p-value <0.05) were estimated. In this study, the area is considered safe and does not pose a health risk.

KEY WORDS : Soil, Radionuclide, Radiological Hazard, Nineveh, Iraq.

INTRODUCTION

Ionizing radiation impact humans from man-made materials and natural sources. Consequently information of radionuclides concentrations and emissions of environmental radionuclides are essential for ensure the level of radiation exposure concentration (Council, 1990; Salih, 2019). Naturally, the radioactivity present in all environments of water, air, food and even our own body contains. The sources of long-lived as ^{226}Ra, ^{232}Th and ^{40}K and their decay series have present the main sources of radiation in soil are (El-Sawy, 2012). Investigation of these radionuclides in soil is an important part of the monitoring program (Li *et al.*, 2013). In analysis of radiation and its direct effects on human health, there are many studies were conducted to estimation the radionuclides in soil, water, vegetables, air, and the radiation in human body (Aswood *et al.*, 2019a; Aswood *et al.*, 2019b; Myasoedov and Pavlotskaya, 1989). After the war of 2003 in Iraq, there are many studied concern about the radionuclides and their effect. In Najaf, Iraq studied of concentrations of radionuclides in agricultural soil in different regions of Iraq using gamma-ray spectrometry detector NaI(Tl) (Hamza *et al.*, 2019; Adhab and Alsabari, 2020; Makki *et al.*, 2014; Kadim *et al.*, 2020; Aswood *et al.*, 2018; Alsalihi *et al.*, 2017; Majeed *et al.*, 2014). Naturally, the concentrations of the radionuclides depends on the geographical conditions and geological of the region (Yaprak and Aslani, 2010). In the current study, the concentrations of radionuclides and radiation hazard indices, PC and P-value for soil samples from right side of Nineveh, Iraq was estimated.

METHODOLOGY

Study area

The study area is located in north western Iraq. It

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shares borders with Syria from west, Turkey from North and from east are Erbil, Ramadi and Salahaldain from South. Nineveh is the third largest governorate in terms of size. Its total land area is estimated at 37,323 km^2 (8.6% the total size of Iraq). The provincial capital is Mosul, located in the north-east. Telfair is another major city in Nineveh, located approximately 30 miles northwest of Mosul city. The Tigris and Greater Zab rivers irrigate much of Mosul. The Tigris river extends from the governorate's northwest to the south. Five schools on the right coast of Mosul were chosen after to find out the radiation levels and compare them with previous studies, as shown in the map below.

Samples sites

Sample Collection and Preparation

Soil samples were collected at depth up at 20 cm, 20 soil samples were collected from five school sites in areas on the right side, 6 km from the center, Al Sahabi School for Boys (AlS), Al-Tabayeen School for Boys in Musheirefah (AlT), the old area of the Prophet Shit Aliyat Al Salam from Al-Watan Boys School (AlW), Hittin Boys School (HIT) and Abi-Tammam School (AbT) for Boys. Each sample was dried at 100 C^o for 24 hours (IAEA, 1989) then, sieved with a mesh to produce particle sizes less than 0.75 mm to get a homogeneous powder with a weight of (1 Kg). All the samples stored for 30 day to allow a radioactive balance between ^{226}Ra and ^{232}Th and shortlived (IAEA, 1989; Avella *et al.,* 2005).

Statistical Analysis

Statistical descriptions were performed using SPSS program, standard version (20.0) to analysis the data was carried out by frequency distributions (P.C) to assess the statistical significance in all parameters measured in the soil samples.

Gamma spectrum analysis

Activity of ^{226}Ra, ^{232} Th and ^{40} K were determined by NaI (Tl) detector. This detector connected with crystal dimensions (3"x3"), supplied by Alpha spectra, Inc.-12I12/ 3. A lead shielding as the circulator which was 5 cm in thickness, 10 cm in inner diameter and 50 cm in high surrounded the detector to reduce the background radiation. Measurements and spectroscopy are calculated using the MAESTRO-32 software on a windows computer. Standard sources, ^{22}Na, ^{137}Cs, ^{60}Co, ^{133}Ba and ^{152}Eu from the IAEA, set no. 34 were used to calibrate energy and measured the absolute efficiency. The Concentrations of natural radionuclides were calculated by equation below (Aswood *et al.,* 2019a).

$$A = \frac{N_{net}}{\varepsilon . I_{\gamma} . m . t} \quad .. 1$$

where N_{net} represent the net count (area under the specified energy peak after back ground subtraction) in (c/s), ε is the efficiency of the detector, I_γ is the transition probability of the emitted gamma ray, *t* is the time (5 hours) for spectrum

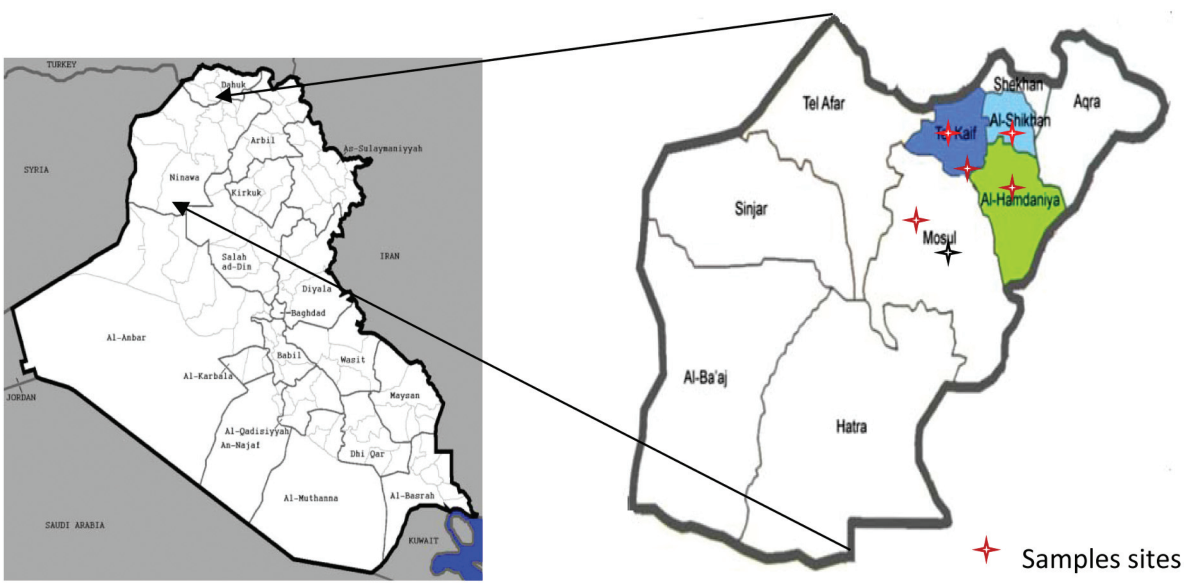

Fig. 1. Maps of study area (Nineveh) Iraq.

collected, and *m* is the sample weight (Kg).

Calculation of Concentration of Radionuclide (ppm)

The measured activity concentrations of ^{232}Th, ^{238}U and ^{40}K (Bq/ Kg) can be converted into concentrations of ^{232}Th, ^{238}U (in ppm) and ^{40}K (in percent) by using conversion factors where, [^{238}U; 1 ppm = 12.35 Bq kg^{-1}; ^{232}Th; 1 ppm = 4.06 Bq kg^{-1}]. Whereas 1% of ^{40}K = 313 Bq kg^{-1} (IAEA, 1989; UNSCEAR, 2000).

Radiological Hazard

The relationship between natural radionuclides and the risks were determined from the equation below.

Representative level index (RLI)

To estimate the level of associated gamma radioactivity for the radionuclides as the representative level index, which given by the following expression:

$$RLI = \frac{1}{150}A_{Ra} + \frac{1}{100}A_{Th} + \frac{1}{1500}A_K \quad ..2$$

Where the A_{Ra}, A_{Th} and A_K are represented the concentrations by Bq/Kg, respectively.

Representative Alpha index (I_a)

From the equation below, the alpha index which was calculated for the samples, by using the equation below (Adhab and Alsabari, 2020; Ziqiang *et al.*, 1988):

$$I_\alpha = \frac{A_{Ra}}{200} \quad ..3$$

Concentration index I_C

To estimate Gamma activity concentration index IC (Bq/ Kg), the following equation was relied upon (Dallner, 2000).

$$I_c = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad ..4$$

Activity Utilization Index (AUI)

In order to calculation of air dose rates from different groups of three radionuclides which given by the following expression (Kolo *et al.*, 2015):

$$AUI = f_{Ra}\frac{A_{Ra}}{50} + f_{Th}\frac{A_{Th}}{50} + f_K\frac{A_K}{500} \quad ..5$$

Where f_{Ra}, f_{Th} and f_K are the fractional contribution to the total dose rate in air due to gamma radiation from the actual concentration of ^{226}Ra , ^{232}Th and ^{40}K , respectively (Ramasamy *et al.*, 2011).

Annual Effective Dose Equivalent (AEDE)

Exposure risk to any individual due to absorbed dose rate is estimated in term of the AEDE. The AEDE was estimated by using the following formula given by (UNSCEAR , 2000).

$$AEDE = D_R \times N_H \times O \times F \quad ..6$$

where N_H is the number of hours in one year (8766 h), O is the outdoor and indoor occupancy factor (0.2, o.8) respectively, and F is the conversion coefficient from the absorbed dose in the air to effective dose received by adults (0.7 Sv Gy^{-1}).

Assuming that an individual spends average of 80 % of his time indoor, the outdoor ($D_{eff\ Outdoor}$) and indoor annual effective doses equivalent has been obtained by

$$D_{efftot}(mSv/y) = D_{effOut} + D_{effIn} \quad ..7$$

Excess Lifetime Cancer Risk (ELCR)

To calculate the excess lifetime cancer risk due to gamma-ray radiation the following equation (Alhous *et al.*, 2020; Alshahri, 2019; Hamza *et al.*, 2020).

$$ELCR = AEDE \times LS \times FR \quad ..8$$

where *AEDE* (mSv/year) was represented the total of Annual Effective Dose Equivalent ($AEDE_{outdoor} + AEDE_{indoor}$). *LS* is a mean life span (approximately 65 years), and *RF* is the risk factor (1/Sv), which reflects the fatal cancer risk per sievert

Annual Gonadal Dose Equivalent (AGDE)

The impacts of radiation on all living cells are varied, and these impacts can lead to the mutation or death cells. The AGDE due to the concentration of ^{226}Ra, ^{232}Th, and ^{40}K was calculated by using the equation(Arafa, 2004):

$$AGED = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_K \quad ..9$$

RESULTS AND DISCUSSION

The activity of 20 soil samples collected from five schools in Nineveh, Iraq has been investigated. A NaI (Tl) detector was used to calculate the concentration of ^{226}Ra, ^{232}Th and ^{40}K and present in

Table1. From Table 1, the highest concentrations of ^{226}Ra, ^{232}Th and ^{40}K have been measured to be 5.07, 5.94 in Al-Sahabi and 4.38% in Al-Tabayeen respectively. On the other side, the lowest concentrations of ^{226}Ra, ^{232}Th and ^{40}K have been determined to be 1.53, 1.32 at Hittin, and 0.99 % at Abi-Tammam school, respectively. On the other side, the average concentrations have food to1.53, 1.32

Table 1. The concentration (ppm) of ^{226}Ra, ^{232}Th and ^{40}K % in the soil samples under study.

ID	Locations	^{226}Ra	^{232}Th	^{40}K %
RS01	Al-Sahabi	2.18	1.06	3.17
RS02		5.07	5.94	3.34
RS03		0.08	0.87	3.94
RS04		4.87	1.04	3.77
RS05	Al-Tabayeen	3.65	3.64	4.38
RS06		0.10	1.21	3.75
RS07		2.50	0.93	3.37
RS08		0.24	1.26	2.99
RS09	Al-Watan	0.79	1.39	3.19
RS10		3.24	0.21	2.93
RS11		1.23	0.62	4.25
RS12		1.15	0.70	2.75
RS13	Hittin	0.09	0.70	3.47
RS14		1.34	0.96	2.46
RS15		1.63	0.14	2.44
RS16		0.43	0.92	2.59
RS17	Abi-Tammam	1.09	1.41	2.43
RS18		0.45	1.36	2.63
RS19	.	0.24	1.24	0.99
RS20		0.16	0.83	1.46
Ave.		1.53	1.32	3.02
World level (UNSCAER, 2000)		2.64	11.01	1.37

Table 3. The ratio among the ^{226}Ra, ^{232}Th and ^{40}K in the soil samples under study.

ID	Ratios		
	^{232}Th - ^{226}Ra	^{40}K-^{226}Ra	^{40}K-^{232}Th
RS01	0.16	36.7136	228.944
RS02	0.39	16.5491	42.94159
RS03	3.42	1180.7478	345.0237
RS04	0.07	19.4539	276.1525
RS05	0.33	30.1393	91.80197
RS06	3.94	928.6121	235.9665
RS07	0.12	33.8750	277.3928
RS08	1.71	310.9025	181.7491
RS09	0.58	102.2509	174.9289
RS10	0.02	22.6662	1055.307
RS11	0.17	87.1834	522.2037
RS12	0.20	59.9759	298.014
RS13	2.61	989.5179	378.4984
RS14	0.24	46.3430	195.4006
RS15	0.03	37.6036	1299.871
RS16	0.71	152.0524	215.8229
RS17	0.43	55.7560	130.983
RS18	0.98	145.6884	148.2249
RS19	1.68	103.6095	61.73707
RS20	1.67	224.9117	134.2806
Ave.	0.97	229.2276	314.7622
Max.	3.94	1180.7478	1299.87

Table 2. Radiological hazard Indices in soil Samples collected from Nineveh

ID	RLI	AUI	I_C	Iá	AGDE(mSv y^{-1})	AEDE(mSv/year)	ELCR $*10^{-3}$
RS01	0.88	0.38	0.44	0.13	0.41	0.43	1.40
RS02	1.35	0.96	0.68	0.31	0.62	0.66	2.16
RS03	0.86	0.15	0.43	0.01	0.40	0.42	1.37
RS04	1.22	0.70	0.61	0.30	0.57	0.59	1.95
RS05	1.36	0.71	0.68	0.23	0.63	0.67	2.16
RS06	0.83	0.167	0.42	0.01	0.39	0.41	1.33
RS07	0.94	0.42	0.47	0.15	0.44	0.46	1.50
RS08	0.69	0.17	0.35	0.02	0.32	0.34	1.11
RS09	0.78	0.24	0.39	0.05	0.37	0.38	1.25
RS10	0.88	0.46	0.44	0.20	0.41	0.43	1.40
RS11	1.01	0.28	0.50	0.08	0.47	0.49	1.60
RS12	0.69	0.24	0.35	0.07	0.32	0.34	1.10
RS13	0.75	0.13	0.38	0.01	0.35	0.37	1.20
RS14	0.66	0.26	0.33	0.08	0.31	0.32	1.05
RS15	0.65	0.26	0.32	0.10	0.30	0.32	1.03
RS16	0.61	0.16	0.30	0.03	0.28	0.29	0.97
RS17	0.65	0.26	0.32	0.07	0.30	0.32	1.04
RS18	0.64	0.19	0.32	0.03	0.29	0.31	1.02
RS19	0.28	0.11	0.14	0.02	0.13	0.14	0.44
RS20	0.35	0.09	0.17	0.01	0.16	0.17	0.56

Table 4. The results of SPSS to get radionuclide concentrations and radiological hazard indicators to get

		Conc. (ppm) U	Percentage K	Conc. (ppm) Th	Index (Iá)	Index (Ic)	Index (AUI)	Index (RLI) (mSv/year)	Gonadal dose 10^{-3}	Cancer risk*	K/Ra	K/Th	Th/Ra
Conc. (ppm) U	Pearson Correlation	1											
	Sig. (2-tailed)												
	N	20											
Percentage K	Pearson Correlation	.367	1										
	Sig. (2-tailed)	.112											
	N	20	20										
Conc.(ppm)Th	Pearson Correlation	.547*	.231	1									
	Sig. (2-tailed)	.013	.327										
	N	20	20	20									
Index(Iá)	Pearson Correlation	1.000**	.367	.547*	1								
	Sig. (2-tailed)	.000	.112	.013									
	N	20	20	20	20								
Index(Ic)	Pearson Correlation	.794**	.838**	.584**	.794**	1							
	Sig. (2-tailed)	.000	.000	.007	.000								
	N	20	20	20	20	20							
Index(AUI)	Pearson Correlation	.968**	.445*	.726**	.968**	.861**	1						
	Sig. (2-tailed)	.000	.049	.000	.000	.000							
	N	20	20	20	20	20	20						
Index(RLI)	Pearson Correlation	.794**	.838**	.584**	.794**	1.000**	.861**	1					
	Sig. (2-tailed)	.000	.000	.007	.000	.000	.000						
	N	20	20	20	20	20	20	20					
Gonadal dosem	Pearson Correlation	.789**	.846**	.569**	.789**	1.000**	.854**	1.000**	1				
	Sig. (2-tailed)	.000	.000	.009	.000	.000	.000	.000					
	N	20	20	20	20	20	20	20	20				
Cancer risk	Pearson Correlation	.793**	.838**	.587**	.793**	1.000**	.861**	1.000**	1.000**	1			
(LCER)*10^{-3}	Sig. (2-tailed)	.000	.000	.007	.000	.000	.000	.000	.000				
	N	20	20	20	20	20	20	2020	20				
K/Ra	Pearson Correlation	-.513-*	.284	-.171-	-.513-*	-.091-	-.422-	-.091-	-.085-	-.090-	1		
	Sig. (2-tailed)	.021	.224	.470	.021	.703	.064	.702	.721	.705			
	N	20	20	20	20	20	20	20	20	20	20		
K/Th	Pearson Correlation	.092	.045	-.476-*	.092	-.019-	-.055-	-.019-	-.010-	-.021-	-.045-	1	
	Sig. (2-tailed)	.701	.852	.034	.701	.938	.817	.938	.968	.929	.850		
	N	20	20	20	20	20	20	20	20	20	20	20	
Th/Ra	Pearson Correlation	-.598-**	.057	-.097-	-.598-**	-.259-	-.490-*	-.259-	-.257-	-.258-	.920**	-.217-	1
	Sig. (2-tailed)	.005	.812	.683	.005	.270	.028	.269	.273	.273	.000	.358	
	N	20	20	20	20	20	20	20	20	20	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

and 3.02% respectively. Naturally, the natural radionuclides are varied from region to another region due to the geographical conditions and geological from region to another region in the world (UNSCAER, 2000). The concentrations of ^{226}Ra and ^{232}Th are less than the permissible limits globally as noticed in UNSCAER, 2000 as mentioned in Table 1. Decidedly, the concentration of ^{40}K% is highest from acceptable level recommended by the UNSCAER2000. Perhaps the reason of the higher concentrations of radioactive in schools, related to the war after 2003 and the war with ISIS.

Radiological hazard indicters are presented in Table 2, the numbers indicted that the average have been to be 0.81, 0.32, 0.40, 0.09, 0.37 (mSv/y), 0.39 (mSv/year) and 1.28 x 10^{-3} for RLI, AUI, I_c, $I_á$, AGED, AEDE and ELCR respectively. The average of all the parameters of the radiological hazard are lower than the recommended level by UNSCEAR, 2000 as shown in Table 2.

The ratios of (^{232}Th - ^{226}Ra), (^{40}K - ^{226}Ra) and (^{40}K - ^{232}Th) have been found as shown in Table 3. From this Table, the ratios were higher than average world as noticed in UNSCEAR, 2000. SPSS program was used to find the relationship between radionuclide concentrations and radiological hazard indicators to get the P.C as shown in Table 4. There are direct strong relation and positive between the concentrations of ^{226}Ra, ^{232}Th and ^{40}K %, where it was significant (p-value < 0.05). It turns out that there is a strong statistical significance. On the other side, P.C was showed significant strong positive correlations for each parameter of radiological hazards. A correlation variables index to not significant (P = 0.900) were found between (^{232}Th-^{226}Ra) and (^{40}K-^{226}Ra). Whereas, an inverse relationship and there is no statistical significance between (^{40}K-^{232}Th), (^{232}Th-^{226}Ra). Finally, there is good statistical significance between, gamma Radiation Representative level index (RLI), Representative Alpha index (Iá) , Gamma activity concentration index I_C , Activity Utilization Index (AUI), Annual Gonadal Dose Equivalent (AGDE) and Excess Lifetime Cancer Risk (ELCR) a strong and statistically significant.

CONCLUSION

The activity of twenty soil samples collected from five schools in Nineveh, Iraq has been measured by NaI (Tl) detector to calculate the concentration of ^{226}Ra, ^{232}Th and ^{40}K. The average concentration of ^{226}Ra, ^{232}Th and ^{40}K (ppm) has been found to be 1.53, 1.32 and 3.02% respectively. The concentrations of ^{226}Ra and ^{232}Th are below the permission level as mentioned in UNSCEAR, 200, whereas, the concentration of ^{40}K is higher than the permission level as noticed in UNSCEAR. The parameters of Radiological hazard were calculated and the results have shown below the recommendation level as mentioned in UNSCEAR. P.C. is good significant in all comparisons except (^{40}K-^{232}Th), (^{232}Th-^{226}Ra).

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