RESEARCH ARTICLE

Calculation of radiological risks for selected soil samples from the north of Kufa district in Najaf, Iraq

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Abstract

Objective: To evaluate radioactivity levels in soil samples and their physical impact on the population.

Methods: The experimental radiation study was conducted in northern Kufa, Al Najaf Governorate, Iraq, in March 2020 by researchers from the Kufa University, Iraq and comprised soil samples. A gamma spectrometer equipped with a sodium iodide detector activated with a trace amount of thallium was used to calculate the concentration of radium, thorium and potassium. Data was analysed using SPSS 20.

Results: There were 30 samples. The average concentration of Radium, Thorium and Potassium was (0.824± 0.392)ppm, (1.536± 0.645)ppm and(0.597± 0.195)%, respectively, and the radiation hazards were lower than the permissible levels. The reported value of excess lifetime cancer risk was (1.2819 ±0.156)×10-^{3}, and the annual gonadal equivalent dose (AGED) was 116.496± 41.255 (mSv. y-^{1}), which was lower than the recommended limit. There was a positive, strong and significant relationship of radium with all the variables ($p<0.05$) studied except with potassium ($p>0.05$). Thorium was positively and significantly associated with all the variables ($p<0.05$).

Conclusion: The study area was found to be safe and there was no relationship between the radiation levels of the studied nuclides and the risk of cancer.

Key Words: Thorium, Radium, Sodium Iodide, Thallium, Radioactivity, Soil, Potassium Radioisotopes

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Introduction

In general, uranium238 (^{238}U), 235U and thorium (^{232}Th) chains, which are radionuclide materials with very long half-lives, are dispersed broadly on both land and water. Their existence goes back to when the earth was first formed 4.5 billion years ago. Such nuclides terminate in the stable isotopes of lead (Pb) nuclide ionising radiation and affect humans through man-made materials and natural sources. Consequently, collecting information on radionuclide concentrations and environmental radionuclides emissions is vital to guarantee the level of radiation exposure concentration[1]. Radioactivity is even present in the human body. The sources of radium (^{226}Ra), ^{232}Th and potassium (^{40}K) and their decay patterns represent the principal sources of radiation in soil[2]. Investigation of such radionuclides is considered a vital part of any monitoring programme[3]. Studies have been conducted to estimate the radionuclides in soil, water, vegetables, air and the human body and their direct influences on human wellbeing[4]. After the 2003 war in Iraq, many studies were conducted on radionuclide concentrations in farming soils in different regions of Najaf, Iraq, and they mainly used gamma-ray spectrometry sodium iodide detector activated with a trace amount of thallium (NaI[Tl])[5,6]. Different areas of Najaf were studied, and the results were mostly within permissible limits[7]. Study of a group of heavy metals in the soil rely on the geographical conditions and the geology of the region[8]. The correlation among the radiation variables of different soil samples along the Karbala-Najaf Road was studied[9]. Activity concentration of ^{238} U, ^{232}Th and ^{40} K averaged 32.9Bq.kg^{-1} (Najaf gypsum), 179.32Bq.kg-1 (Karbala cement) and 1.98Bq.kg^{-1} (Najaf), respectively[10]. A total of 30 soil samples were taken from Study area to evaluate the specific activity of ^{226}Ra, ^{232}Th, and ^{40}K nuclei, and the obtained values were within acceptable limits except for one of the values of the absorbed interior[5]. In a previous study, samples were evaluated in the Nineveh Governorate of Iraq), and the values obtained did not pose any significant health threat to human lives[11].

The current study was planned to determine the concentrations of radionuclides and radioactive hazard indicators of soil samples in northern Kufa.

Materials and Methods

The experimental radiation study was conducted in northern Kufa, Al Najaf Governorate, Iraq, in March 2020, by researchers from the University of Kufa and comprised soil samples. Using the global positioning system (GPS), latitude and longitude coordinates for soil samples were worked out, and the Golden Software Surfer version

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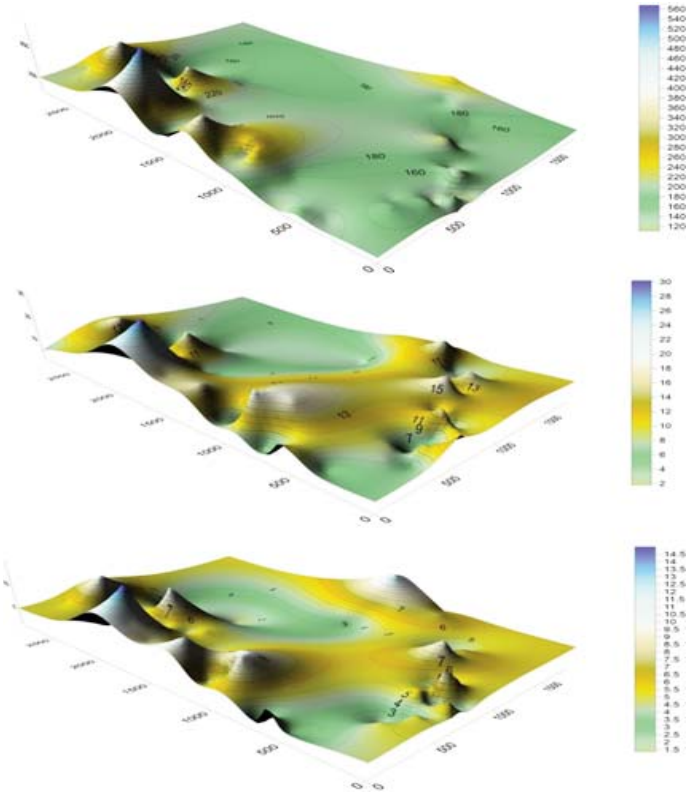

Figure: Three-dimensional (3D) map of the elemantel concentration of radium (^{226}Ra), thorium (^{232}Th) and potassium (^{40}K%).

17was used for radiographic mapping of the study area was done (Figure)[12].

The collected soil samples were first dried by heating in an oven at 80°C for one day to remove the moisture completely and to obtain a stable weight. The dried samples were then prepared for the measurement process. They were ground and sieved using stainless steel with an 0.8mm mesh size to ensure a homogenous and high-quality sample. The samples weighed 1kg, and this ensured geometric homogeneity around the detector. To reach the state of the secular equilibrium between ^{226}Ra and ^{232}Th nuclei and its short-lived decay products, one month was allowed before initiating radioactivity measurements of the samples[13].

The activity of ^{226}Ra, ^{232}Th and 40K was determined by Gamma- ray spectrometer consists of a scintillation detector NaI(Tl) type of (3"×3") crystal dimension, supplied by (Alpha Spectra, Inc.-12I12/3), coupled with a multi-channel analyzer (MCA) (ORTEC-Digi Base, UK) with range of 4096 channel joined with ADC (Analog to Digital Convertor, UK) unit, through interface, made in United Kingdom(UK). The spectroscopic measurements and analysis were performed via the (MAESTRO-32, UK) software into the PC of the laboratory. Standard sources sodium (^{22}Na), cobalt (^{60}Co), barium (^{133}Ba), caesium (^{137}Cs) and europium (^{152}Eu), were utilised to measure the absolute efficiency, and to adjust the energy. The assessments were done using various equations described in literature[14-22].

The concentrations of natural radionuclides were calculated after the radioactivity was extracted, and it was used to find the elemental concentrations in terms of parts per million (ppm) unit using the equation

$$A = \frac{N_{net}}{\varepsilon . I_G . m . t}$$

in which N_{net} was the net count in (c.s^{-1}) representing the area under an indicated energy peak after background deduction, ϵ was the efficiency of the detector, IG was the transition possibility of the released gamma-ray, t was the time of the collected spectrum (4 hrs), and m was the weight of the sample (1kg).

After the determination of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq.Kg-^{1}) were transformed into elemental concentrations of ^{226}Ra (ppm), ^{232}Th (ppm), and 40K (%) by using conversion factors[22]: ^{226}Ra 1 ppm = 12.35Bq.kg^{-1}, 232Th 1 ppm = 4.06Bq.kg^{-1}, and ^{40}K 1% = 313Bq.kg^{-1}.

Representative level index (RLI) was calculated to predict the level of gamma radioactivity for the radionuclides using the equation

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

in which ARa, ATh, and AK were represented by the concentrations, respectively.

$$I_\alpha = \frac{A_{Ra}}{200}$$

In view of the dangers of alpha particles to humans[15,16], representative alpha index (Iα) was measured using the equation

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

Concentration index (IC) was calculated using the equation

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

Activity utilisation index (AUI): of the radionuclides was calculated using the equation

in which fRa, fTh and fk were the fractional contribution to the total dose rate in the air due to gamma radiation from the actual concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

For both indoor and outdoor settings, the annual effective doses were acquired and the total annual effective dose equivalent (AEDE) , mSv.y-1, was determined While assuming that a person spends about 80% of the lifetime indoors. The equation used was

$$AEDE_{tot}(mSv.y^{-1}) = AEDE_{in} + AEDE_{out}$$

Excess lifetime cancer risk (ELCR) was determined using the equation

$$ELCR = AEDE \times LS \times RF$$

In which ***LS*** was the approximate mean life span (70 years), RF was the risk factor (Sv-1) reflecting the risk of fatal cancer per Sievert for stochastic effects.

The annual gonadal equivalent dose (AGED) was calculated using the equation

$$AGED = 3.09 A_{Ra} + 4.18 A_{Th} + 0.314 A_K$$

The exposure rate ($\dot{X}$) of gamma-ray in the air at 1m above an enormously extended and thick slab due to ^{226}Ra, ^{232}Th series and ^{40}K uniformly distributed in the material was calculate using the euqation

$$X\ \mu R.h^{-1} = 1.90\ A_U + 2.82\ A_{Th} + 0.197 A_K$$

Data was analysed using SPSS 20. The association between the samples was evaluated using Pearson correlation coefficient. $P<0.05$ was considered significant.

Results

There were 30 samples. The average concentration of ^{226}Ra, ^{232}Th and ^{40}K was (0.824± 0.392)ppm, (1.536± 0.645)ppm and(0.597± 0.195)%,, respectively, and the radiation hazards were lower than the permissible levels (Table 1).

The reported value of ELCR was (1.281±0.156) ×10-3, and the AGED was 116.496± 41.255 (mSv. y-1), which was lower than the recommended limit (Table 2).

There was a positive, strong and significant relationship of ^{226}Ra with all the variables ($p<0.05$) studied except with ^{40}K ($p>0.05$). Besides, ^{232}Th was positively and significantly associated with all the variables ($p<0.05$).

Discussion

Using the equations listed previously[14-22], elemental concentrations and other radiation hazards were calculated for soil samples from 30 sites. The concentrations of ^{226}Ra, ^{232}Th and 40K% were less than the the permissible limits globally[23,24].

The ratio of ^{232}Th-^{226}Ra was a slightly higher than the average value verified by the United Nations Scientific Committee on the Effects of Atomic Radiation

Table-1: Latitude and longitude coordinates along with the concentration of radium (226Ra), thorium (232Th) and potassium (40K%) and their ratio in the examined soil samples.

ID	Geographical position		Elemental Concentrations(ppm)			Ratio		
	Latitude	Longitude	^{226}Ra	^{232}Th	^{40}K %	^{232}Th - ^{226}Ra	^{40}K-^{226}Ra	^{40}K-^{232}Th
MC1	32°02'56.5"N	44°22'33.8"E	0.738	1.624	0.464	0.724	15.916	21.976
MC2	32°02'40.5"N	44°22'09.2"E	0.823	1.209	0.608	0.484	18.745	38.743
MC3	32°02'36.6"N	44°21'57.3"E	0.710	1.529	0.46	0.709	16.438	23.176
MC4	32°02'36.1"N	44°21'51.0"E	0.393	0.73	0.404	0.611	26.045	42.627
MC5	32°02'40.3"N	44°21'28.1"E	1.012	1.32	0.7	0.43	17.529	40.796
MC6	32°03'57.4"N	44°21'13.5"E	1.525	2.916	1.13	0.63	18.788	29.841
MC7	32°03'33.8"N	44°21'02.4"E	0.388	1.045	0.572	0.886	37.353	42.155
MC8	32°03'41.9"N	44°21'11.6"E	0.742	2.09	0.701	0.927	23.935	25.815
MC9	32°02'33.1"N	44°21'56.3"E	0.669	0.915	0.541	0.45	20.512	45.546
MC10	32°03'42.1"N	44°21'34.6"E	0.247	1.1	0.647	1.467	66.376	45.247
MC11	32°02'35.0"N	44°21'56.8"E	1.196	1.876	0.504	0.516	10.684	20.691
MC12	32°03'20.3"N	44°21'21.1"E	0.487	1.41	0.611	0.954	31.847	33.386
MC13	32°03'22.0"N	44°21'44.7"E	1.309	2.525	0.542	0.635	10.503	16.539
MC14	32°02'34.8"N	44°21'55.6"E	0.475	1.184	0.384	0.821	20.501	24.959
MC15	32°02'32.7"N	44°21'48.8"E	0.599	1.207	0.595	0.663	25.175	37.958
MC16	32°02'34.8"N	44°21'37.4"E	1.261	1.002	0.491	0.262	9.861	37.702
MC17	32°02'35.9"N	44°21'55.8"E	1.453	1.645	0.501	0.373	8.747	23.47
MC18	32°02'40.8"N	44°22'13.6"E	0.393	0.883	0.682	0.739	43.996	59.496
MC19	32°03'47.7"N	44°21'08.5"E	0.832	2.945	0.651	1.165	19.849	17.032

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MC20	32°03'07.9"N	44°22'30.4"E	1.359	2.828	1.258	0.685	23.466	34.25
MC21	32°03'10.4"N	44°21'20.5"E	1.000	1.697	0.388	0.559	9.83	17.591
MC22	32°02'47.6"N	44°21'24.7"E	0.352	1.068	0.464	0.998	33.38	33.442
MC23	32°02'53.4"N	44°21'21.8"E	0.940	0.834	0.339	0.292	9.155	31.34
MC24	32°02'31.3"N	44°21'52.3"E	0.710	1.688	0.591	0.783	21.105	26.948
MC25	32°02'30.2"N	44°21'49.6"E	0.779	1.147	0.506	0.484	16.469	33.992
MC26	32°02'38.9"N	44°21'59.3"E	1.581	2.493	0.732	0.519	11.73	22.593
MC27	32°02'41.3"N	44°22'06.4"E	0.599	1.109	0.51	0.609	21.55	35.376
MC28	32°02'44.7"N	44°22'21.6"E	0.120	1.135	0.602	3.117	127.307	40.838
MC29	32°03'01.6"N	44°21'17.9"E	1.033	1.358	0.543	0.433	13.332	30.813
MC30	32°02'32.4"N	44°21'44.6"E	0.959	0.973	0.405	0.334	10.693	32.014
Max.			1.581	2.945	1.258	3.117	127.307	59.496
Min.			0.12	0.73	0.339	0.262	8.747	16.539
Average ±SD			0.824±0.392	1.536±0.645	0.597±0.195	0.8011±0.520	27.402±22.874	2.574±9.967
Worldwide [24,25]			1.8	9	1.5	0.86	11.43	13.33

Table-2: Radiological hazard indices and radiation levels found in the soil samples.

ID	RLI	AUI	IC	Iα	AGED*10^{-3} (mSv y^{-1})	AEDE (mSv.y^{-1})	ELCR *10-
MC1	0.224	0.176	0.112	0.046	101.337	0.1103	0.386
MC2	0.244	0.169	0.122	0.051	111.733	0.1200	0.42
MC3	0.217	0.168	0.108	0.044	98.278	0.1068	0.374
MC4	0.146	0.091	0.073	0.024	67.1	0.0720	0.252
MC5	0.283	0.198	0.141	0.062	129.789	0.1392	0.487
MC6	0.48	0.346	0.24	0.094	218.784	0.2364	0.828
MC7	0.194	0.11	0.097	0.024	88.823	0.0955	0.334
MC8	0.292	0.205	0.146	0.046	132.713	0.1442	0.505
MC9	0.205	0.135	0.103	0.041	94.259	0.1009	0.353
MC10	0.2	0.099	0.1	0.015	91.663	0.0986	0.345
MC11	0.28	0.242	0.14	0.074	127.076	0.1379	0.483
MC12	0.225	0.14	0.112	0.03	102.619	0.1109	0.388
MC13	0.324	0.287	0.162	0.081	146.145	0.1596	0.559
MC14	0.167	0.122	0.084	0.029	75.962	0.0825	0.289
MC15	0.223	0.143	0.111	0.037	101.883	0.1096	0.384
MC16	0.247	0.206	0.123	0.078	113.347	0.1213	0.424
MC17	0.291	0.259	0.146	0.09	132.644	0.1432	0.501
MC18	0.211	0.106	0.105	0.024	97.072	0.1037	0.363
MC19	0.324	0.256	0.162	0.051	145.812	0.1603	0.561
MC20	0.489	0.326	0.245	0.084	223.554	0.2411	0.844
MC21	0.232	0.207	0.116	0.062	105.072	0.1145	0.401
MC22	0.169	0.105	0.085	0.022	77.208	0.0835	0.292
MC23	0.182	0.157	0.091	0.058	83.383	0.0895	0.313
MC24	0.25	0.179	0.125	0.044	113.822	0.1234	0.432
MC25	0.216	0.158	0.108	0.048	98.959	0.1065	0.373
MC26	0.384	0.322	0.192	0.098	174.597	0.1893	0.662
MC27	0.201	0.136	0.1	0.037	91.786	0.0989	0.346
MC28	0.182	0.085	0.091	0.007	83.024	0.0896	0.314
MC29	0.254	0.199	0.127	0.064	115.908	0.1248	0.437
MC30	0.203	0.168	0.101	0.059	92.874	0.0997	0.349
Max	0.489	0.346	0.245	0.098	223.554	0.2411	0.844
Min	0.146	0.085	0.073	0.007	67.1	0.0720	0.252
Average ±SD.	0.255±0.090	0.185± 0.07	0.127±0.04	0.050±0.02	116.496±41.25	0.125±0.04	0.440±0.156
Worldwide [25,26]	< 1	< 1	< 1	< 1	300	0.48	1.45

RLI: Representative level index, AUI: Activity utilisation index, IC: Concentration index, Iα: Representative alpha index, AEDE: Annual effective dose equivalent, AGED: Annual gonadal dose equivalent, ELCR: Excess lifetime cancer risk.

(UNSCEAR)[22].

Radiological hazard indicters were noted, and the average values of all the parameters were lower than the recommended level[22]. Also, the exposure rate was within the permissible limits [22].

There was a positive, strong and significant relationship of ^{226}Ra with all the variables ($p<0.05$) studied except with ^{40}K ($p>0.05$). Besides, ^{232}Th was positively and significantly associated with all the variables ($p<0.05$).

Conclusion

The elemental concentration of 226Ra, 232Th and 40K% was below the recommended levels, indicating the environment was safe for human wellbeing.

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