ORIGINAL ARTICLE

Distribution of radionuclides in the soils and assessment of radiation hazards in AL Najaf, Iraq: A cross sectional analysis

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Abstract

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

Method: The experimental radiation study was conducted by researchers belonging to the Kufa University in Al-Najaf, Iraq, in August 2020, and comprised soil samples from Al-Rahma area. Sodium iodide detector activated with a trace amount of Thallium with crystal dimensions 3" x 3" was used to calculate the concentration of Radium, Thorium and Potassium.

Results: Among the 15 samples collected, the average ± standard deviation (SD) concentration for Radium, Thorium and Potassium was 0.1776±0.12, 0.726±0.435 and 1.9128±1.105%, respectively. The reported value of excess lifetime cancer risk was 1.2819×10^{-3}.

Conclusion: The area studied was found to be a safe area and did not pose a health threat to the locals.

Key Words: Thorium, Radium, Sodium Iodide, Thallium, Radioactivity, Neoplasms, Soil

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Introduction

Human exposure to naturally occurring radionuclides comes from either artificial or natural sources. Studies have shown that about 80% of these ionising radiations come from natural background radiation, including cosmic rays, radon gas, and terrestrial radionuclides[1]. The ones that form terrestrial radionuclides are series radionuclides of uranium-radium (238U-226Ra), thorium (232Th) together with non-series radionuclides of potassium (40K). The levels of ionising radiations may be exacerbated by human activities[2]. Human-induced activities, such as waste disposal tend to impact negatively on the environment and public health. Some waste products are radioactive and may have originated from industrial activities. Wastes associated with these activities can enhance levels of natural radioactivity in the environment[2]. Ionising radiation has its effect on humans, while man-made materials and natural sources also have an effect, so it is necessary to know the level of exposure to radiation to know the effect of radionuclides. Knowing the concentration level of radiation exposure is necessary to know the effect of the radionuclides[3]. It can be said that radioactivity is present in all types of environments, such as water, air and food[4], and, in fact, it is present even in human bodies. Long-lived sources, such as 226Ra, 232Th and 40K are the main sources of radiation presence in soil. Soil sampling concentrations of 226Ra, 232Th and 40K were reported to be 17.386±1.327, 15.889±0.556 and 553.269±4.997Bq.Kg-1,respectively[5]. Studies have been conducted to estimate the radionuclides in soil, water, vegetables, air and the human body regarding radiation and its influence on human wellbeing[6,7]. After the 2003 war in Iraq, many studies raised concerns about the radionuclides and their effect, using gamma-ray spectrometry detector based on sodium iodide activated with a trace amount of thallium (NaI[Tl]), and these included investigations that were conducted on radionuclides concentrations in agricultural soils in different regions of Najaf[8]. The concentrations of the radionuclides rely on the geographical conditions and the geology of a region, and, as such, assessment of excess lifetime cancer risk (ELCR) of soils samples was done in the Maysan neighbourhood adjacent to the Middle Euphrates Cancer Centre in Najaf, Iraq[9].

The current study was planned to estimate the distribution of radioactive nuclei and radioactive hazards in Al-Rahma area, Najaf, Iraq.

Materials and Methods

The experimental radiation study was conducted in Al-Najaf, Iraq, in August 2020, by researchers from the University of Kufa, Iraq and comprised soil samples from Al-Rahma area. Najaf is located in the southwest of Baghdad, the capital of Iraq, with $864km^2$ area and approximately 60m above sea level, and is considered one of the important cities in Iraq. This is attributed to the many factors, such as the existence of the Najaf sea, which is the most important geographical landmark in

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the city, and the presence of the religious shrine of Imam Ali[10]. The Al-Rahma neighbourhood, about 3km from the shrine, was selected due to the appearance of many cases of cancer in the region. Moreover, it is a popular area with a high population and poor municipal services with unpaved streets, which brings the residents in direct contact with the soil.

Samples were collected from the area. They were dried by heating in an oven at 80°C for one day to eradicate the moisture and obtain a fixed weight. The dried samples were ground and then sieved using stainless steel with a 0.8mm mesh size. This ensured a homogenous and high-quality sample. Using a digital balance, the actual weights of the samples were determined by deducting the cup weight. All samples were packed into a polyethylene beaker, which was then sealed tightly. This was done to ensure a homogenous geometry around the detector. The samples were stored for about one month before initiating radioactivity measurements to obtain secular equilibrium state between ^{226}Ra and ^{232}Th nuclei and their short-lived decay products[11].

Concentrations of ^{226}Ra, ^{232}Th and ^{40}K% were determined using an 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) with range of 4096 channel joined with ADC (Analog to Digital Convertor) unit, through interface, (United Kingdom(UK). The spectroscopic measurements and analysis were performed via the (MAESTRO-32) software into the PC of the laboratory. A circulator lead shielding with thickness 5cm, inner diameter 10cm and height 50cm enclosed the detector to decrease the background radiation. Standard sources sodium (^{22}Na), cobalt (^{60}Co), barium (^{133}Ba), caesium (^{137}Cs) and europium (152Eu), were utilised to measure the absolute efficiency, and to adjust the energy. The concentrations of natural radionuclides were calculated. Specific activity was calculated as per the equations mentioned in literature[10].

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

in which was the net count (c.s^{-1}), which is also represented by the area under a specified energy peak after background subtraction, was detector efficiency, was the transition possibility of the released gamma-ray, t was the time of the collected spectrum (18 000 seconds), and m was the weight of the sample (1kg).

The determined activity concentrations of 226Ra,232Th and 40KBq.Kg^{-1} is transformed into concentrations of ^{226}Ra, ^{232}Th, and 40K using conversion factors. The values are 226Ra, ^{1} ppm = 12.35Bq.Kg^{-1}, 232Th, ^{1} ppm = 4.06Bq.Kg$-^{1}$, and ^{40}K ^{1}% = 313Bq.Kg^{-1}[12].

The relationship between natural radionuclides and the risks was determined using the representative level index (RLI) to predict the level of associated gamma radioactivity for the radionuclides[13]:

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

Rates of air doses from various groups of the three radionuclides were determined using activity utilisation index (AUI)[13].

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

in which f_{Ra}, f_{Th} and f_K, were the fractional contributions to the overall dose rate in the air because of gamma radiation from the actual concentration of the studied activity[14].

Gamma activity was estimated using concentration index (Ic)[15].

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

Representative alpha index (Iα) was calculated for the samples due to the importance of the effect of alpha particles on the human body and its relationship to various cancerous diseases, and it was done in relation to radium and radon[16-18].

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

Exposure hazard to any person caused by absorbed dose rate was predicted in terms of annual effective dose equivalent (AEDE). For both indoor and outdoor, the annual effective doses were acquired, and the total annual effective dose equivalent, mSv.y^{-1}, was determined using an equation cited in literature[19].

$$AEDEtot(mSv.y-^{1}) = \mathrm{AEDEout} + \mathrm{AEDEin}$$

The equation was used with the assumption that a person spends about 80% lifetime indoors (AEDEin). Along with AEDEout the total value (AEDEtot) was calculated.

ELCR was determined by the radiation of gamma-ray [20].

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

In which LS was the approximate mean life span (70 years), and RF was the risk factor ($0.05Sv^{-1}$), reflecting the risk of fatal cancer per Sievert for stochastic effects.

Annual gonadal dose equivalent (AGED) indicates the influence of radiation on live cells, and these influences can lead to cells' mutation or death. AGED was calculated using an equation mentioned in literature[21].

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

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2010 guidelines, gonads are the organs of concern for dosimeter purposes, the primary reproductive organs are the testes in males and the ovaries in females. An increase in the levels of AGED is also recognised to influence the bone marrow that produces red blood cells (RBCs). This may lead to leukaemia, which is often a fatal disease. Other organs of interest are the thyroid, lungs, liver, colon and bladder[12].

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

Results

Among the 15 samples collected, the average ±SD concentration for 226Ra, 232Th and 40K was 0.1776±0.12, 0.7261±0.435 and 1.9128±1.105%, respectively, (Table 1).

Table-1: Elemental concentration of radium (^{226}Ra), thorium (^{232}Th) and potassium ($^{40}K\%$) in the studied soil samples.

ID (sample code)	Elemental concentrations (ppm)		
	^{226}Ra	^{232}Th	^{40}K %
R1	0.2129	0.6310	2.7368
R2	0.1301	0.4948	3.1642
R3	0.1634	0.2488	3.1376
R4	0.0944	0.3794	3.1179
R5	0.3004	0.3155	2.9295
R6	0.0426	0.1390	2.7693
R7	0.0645	0.2418	2.8086
R8	0.1404	0.4920	2.6910
R9	0.4362	1.3009	0.7139
R10	0.0875	1.0382	0.8258
R11	0.0852	1.0841	0.8383
R12	0.1611	0.9076	0.8123
R13	0.3832	1.2981	0.7671
R14	0.0852	1.0354	0.7047
R15	0.1542	1.2981	0.6685
Max.	0.4362	1.3009	3.1642
Min.	0.0426	0.1390	0.6685
Average ±SD	0.1776±0.12	0.7261±0.435	1.9128±1.105
Worldwide[25,26]	1.8	9	1.5

Radiation risk indicators were found to be within permissible radiation limits (Table 2).

There was a significant positive correlation between 226Ra and AUI, and a positive correlation with Iα, while the rest of the variables showed weak relationship (Table 3).

Discussion

The natural radionuclides vary from one region to another due to the variation in geographical and geological conditions[22]. The concentrations of ^{226}Ra and ^{232}Th in the current study were less than the permissible limits globally, but the concentration of $^{40}K\%$ was higher than the acceptable level[22]. The reason for the high concentration of $^{40}K\%$ was perhaps due to the fact that the area was originally agricultural, which saw a few battles in 2004. The highest values of the concentration of $2^{26}Ra$ and ^{232}Th in the current study were found in sample R9, while the lowest values were found in sample R6. On the other hand, the highest value of the $^{40}K\%$ was reported for sample R2, while the lowest was reported for R15. The average of ^{226}Ra and ^{232}Th was lower than the internationally surveyed limit, while the percentage of 40K% was higher than what is permissible globally[23,24]. This might be due to the presence of chemical fertilizers, the nature of the soil, or radioactive contamination that happened during wars. Radiological hazard indicators were also assessed in the current study (Table 2) The averages of all the radiological hazard parameters were lower than the recommended[12].

There was a significant positive correlation between ^{226}Ra and AUI, and a positive correlation with Iα, while the rest of the variables showed weak relationship and can be ignored (Table 3).

On the basis of the findings, it was clear that the main causes of cancer had nothing to do with the soil, and there may be other factors that must be studied, Finally, it is possible to say that after comparison with global sources of radiation levels, the study samples were safe for health, except for radioactive potassium[25,23].

Conclusion

The average concentration of ^{226}Ra and ^{232}Thwere below the allowable levels, while the concentration of ^{40}K was higher than the permissible level.

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Table-2: Radiological hazard indices in the studied soil samples.

ID	RLI	AUI	IC	Iα	AGED (mSv y^{-1})	AEDE (mSv.y^{-1})	ELCR *10^{-3}
R1	0.6142	0.1255	0.3071	0.0131	0.288	0.3015	0.8292
R2	0.6911	0.1203	0.3455	0.0080	0.324	0.3392	0.9327
R3	0.6783	0.1114	0.3391	0.0101	0.319	0.3327	0.9150
R4	0.6738	0.1094	0.3369	0.0058	0.316	0.3306	0.9092
R 5	0.6488	0.1249	0.3244	0.0185	0.305	0.3183	0.8753
R 6	0.5870	0.0828	0.2935	0.0026	0.276	0.2880	0.7919
R7	0.6012	0.0913	0.3006	0.0040	0.283	0.2950	0.8111
R 8	0.5931	0.1092	0.2965	0.0087	0.278	0.2911	0.8005
R 9	0.2377	0.1320	0.1189	0.0269	0.109	0.1172	0.3222
R 10	0.2217	0.0822	0.1109	0.0054	0.102	0.1093	0.3005
R 11	0.2260	0.0845	0.1130	0.0053	0.104	0.1114	0.3063
R 12	0.2196	0.0838	0.1098	0.0099	0.101	0.1082	0.2974
R 13	0.2444	0.1272	0.1222	0.0237	0.112	0.1204	0.3312
R 14	0.1962	0.0786	0.0981	0.0053	0.090	0.0967	0.2660
R 15	0.2050	0.0985	0.1025	0.0095	0.094	0.1012	0.2782
Max	0.6911	0.1320	0.3455	0.0269	0.324	0.3392	0.9327
Min	0.1962	0.0786	0.0981	0.0026	0.090	0.0967	0.2660
Ave. ±SD	0.4427±0.213	0.1042±0.019	0.2213±0.106	0.0110±0.007	0.207±0.101	0.2174±0.104	0.5980±0.287
Worldwide[24,26]	< 1	< 1	< 1	< 1	300*10^{-3}	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.

Table-3: Pearson correlation of the examined parameters.

Variable	Correlation	Laboratory data ^{226}Ra (ppm)	^{232}Th (ppm)	K%	RLI	AUI	IC	Iα	AGED	ELCR
^{226}Ra(ppm)	P. C	1								
	P-value									
^{232}Th(ppm)	P. C	0.422	1							
	P value	0.117								
K%	P. C	-0.249-	-.932-**	1						
	P value	0.371	0.000							
RLI	P. C	-0.191-	-.911-**	.998**	1					
	P value	0.495	0.000	.000						
AUI	P. C	0.785**	-0.013-	.311	.371	1				
	P value	0.001	0.963	.260	.174					
IC	P. C	-.191-	-.911-**	.998**	1.000**	.371	1			
	P value	.495	.000	.000	.000	.174				
Iα	P. C	1.000**	.424	-.250-	-.193-	.784**	-.193-	1		
	P value	.000	.116	.368	.491	.001	.491			
AGED	P. C	-.194-	-.913-**	.998**	1.000**	.367	1.000**	-.196-	1	
	P value	.488	.000	.000	.000	.178	.000	.485		
ELCR	P. C	-.191-	-.911-**	.998**	1.000**	.371	1.000**	.192-	1.000**	1
	P value	.496	.000	.000	.000	.173	.000	.492	.000	

** Correlation significant at 0.01 level (2-tailed).
^{226}Ra: Radium, ^{232}Th: Thorium, ^{40}K%: Potassium, 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.

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