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Natural radionuclides and radiological hazards in sediment samples of the Euphrates River in Al Diwaniyah governorate, Iraq

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► ***Short report***

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ABSTRACT

Background: The radionuclide concentrations of ^{226}Ra, ^{232}Th and ^{40}K were measured in the sediments samples of the Euphrates River in Al-Diwaniyah city, Iraq. ***Materials and Methods***: Effective technique of high purity germanium (HPGe) detector based on a high-resolution gamma spectrometry system was used to determine the specific activity of natural and artificial radionuclide in sediments samples. ***Results***: The present investigated showed that the average values of specific activities of (^{226}Ra, ^{232}Th, and ^{40}K) were 86.015, 48.446, and 764.661 Bq/Kg, respectively. The averages values of the radiological hazards radium equivalent (Ra_{eq}), absorbed dose rate (D_R) and external hazard index (H_{ex}) were 211.3 Bq/kg, 100.9 nGy/h, and 0.56 respectively. Specific activity of ^{137}Cs appeared in some sediment samples, which indicates the presence of industrial pollution in those areas. ***Conclusion***: According to these values, the results of the current study exceeded the global permissible values of the natural radionuclides.

INTRODUCTION

The world is witnessing an increase in the spread of nuclear technology and the expansion of the use of radionuclides in industry, agriculture, medicine, and other nuclear and radiological applications. This may be accompanied by increasing accidents with a significant escalation in the potential risks of external exposure of humans to ionizing radiation, and contamination of internal organs with radionuclides (1). Radiation in the environment has both natural and industrial sources, where exposure to natural radiation is more important than the radiation exposure posed by industrial radioactive sources in the environment (2, 3). Radionuclide's series occur naturally, such as ^{238}U, ^{232}Th, and ^{40}K they are found everywhere in the earth's crust. These radionuclides are very important because they provide useful information and are of even greater concern because of their high solubility and rapid transportability. Knowing the concentrations and distributions in monitoring environmental pollution by natural radioactivity is very important to pay attention to human health (4, 5). Radioactivity is common in rivers and oceans in rocks, soil, sand, and sediments, also common in building and home materials, which contain naturally occurring radioactive materials. In general, it includes the remaining primordial radionuclides since the origin of the earth (6). The subject of our study is radionuclides and their effects on the environment. Radionuclides (natural or synthetic) can be transmitted in different media in the short or long term. Humans and the environment are exposed to the natural background radiation of cosmic rays and terrestrial gamma rays. They are also affected by synthetic radionuclides coming from nuclear reactors and explosions, such as reactor accidents, radioactive waste, and weapons tests, all of which contaminate the soil, sediments, and the atmosphere (6–8). Sediments typically provide information on environmental and geochemical contamination and play an important role in aquatic biology and radioecology (9, 10). Radionuclides travel from the lithosphere to the natural ecosystem through several pathways, such as atmospheric, corrosion of rocks, wind, and water. Sediments are also part of the ecosystem and may be affected by contamination over long periods and large areas. They are also effective and can be detected and followed up easily (10). Radioactive decay is the emission of energy in the form of ionizing radiation. The emitted ionizing radiation can include alpha and beta particles or gamma rays. Some of these forms are stable, while others are unstable, which poses health risks to the exposed people (11–13). The Euphrates River enters the city of Al-Diwaniyah, which starts from the city of Babylon and splits into two sides. It passes through several locations of the city until its path ends in the city of Al-Muthanna, southern Iraq. So that it is very important to monitor the radionuclides content in the Euphrates River. The aim of the current study is to determine the content

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of natural radiation ^{226}Ra, ^{232}Th, K^{40}, also ^{137}Cs as an artificial radionuclide in sediments samples of the Euphrates River in Al-Diwaniyah governorate.

MATERIALS AND METHODES

Samples collection

In the present study, 13 sediment samples were collected from the Euphrates River in Al-Diwaniyah governorate, southern Iraq. A map of the field sampling points and the studied areas (sample sites) is shown in figure 1. The table 1 shows the locations coordinates of the sediment samples.

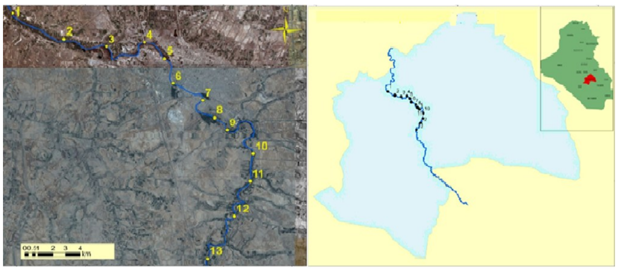

Figure 1. The locations of sediments samples of Euphrates River in Al-Diwaniyah governorate.

Table 1. The coordinates of sediment samples involved in the study.

Sample code	location	Coordinates	
S1	Al-Suniyah, Umm Al-Dahab	° 32.041194N	° 44.785056E
S2	Al-Suniyah, Al- Kubae	° 32.022944N	° 44.824944E
S3	Abu Al-Fadl	° 32.017528N	° 44.857250E
S4	Abu Al-Fadl	° 32.020583N	° 44.886139E
S5	Al-mushmisa	° 32.009028N	° 44.902167E
S6	Al-Rafie	° 31.990583N	° 44.908694E
S7	Sadar Al-Yyusfia	° 31.978750N	° 44.931722E
S8	Al-Taqiyah	° 31.966333N	° 44.940520E
S9	Al-Jazra	° 31.957361N	° 44.950694E
S10	Al- Iantilaqa	° 31.940111N	° 44.970194E
S11	Al-Ratie	° 31.920333N	° 44.968139E
S12	Al-Seeder, Al- Dihaya	° 31.894944N	° 44.955917E
S13	Al-Seeder, Al- Dihaya	31.864639° N	° 44.935278E

Experimental method

The surface sediments collected from 13 different locations along the Euphrates River in Al- Diwaniyah governorate during winter season 2021. After collecting the samples in transparent bags the size of one kilo, each sample is dried in a thermal oven at a temperature of 120 ° C and then left to cool and is sieved through a mesh size of 1.8 mm to remove stones and other dirt. The samples were homogenized, filled and sealed in airtight bags to prevent the leakage of radioactive gases such as radon ^{222}Rn and thoron ^{220}Rn. The pure germanium reagent HPGe model (GC4020, USA) was used as an analytic-type (PNP) reagent with separation energy of (2 keV) at (1332 keV) of ^{60}CO isotope and turned on at temperature of (-176 C°) using liquid nitrogen inside a (Dewar) vessel, the accuracy of the system is 85%.

To reduce the radiation background to a minimum, the detector was surrounded by layers of copper-coated lead, forming a thick shield (10 cm). This system works using the Genie (2000) program, manufactured by Canberra, to analyze the measured spectra, which includes determining the peaks, their energy, and the net area under each peak. Several radioactive sources such as (^{22}Na, ^{137}Cs, ^{60}Co and ^{152}Eu) were used to make the calibration of the system and calculation the efficiency of the detector. Therefore, this system was chosen to be the effective measurement technique and it is the most popular due to its desirable qualities, its high density (5.3 g/cm^3) which makes it have a high ability to stop nuclear radiation in a small way. Thorium ^{232}Th activity was measured through its daughters ^{212}Pb, ^{228}Ac with energy 583.1, 911.1 keV, respectively. Radium ^{226}Ra activity was measured through its daughters ^{214}Bi, ^{214}Pb with energy 609.3, 351.9 keV, respectively. Potassium ^{40}K activity was measured at single energy 1460.8 keV. While, the activity of cesium ^{137}Cs was measured at energy 662 keV.

Calculations

The specific activity (As) of the radionuclides was calculated from the background subtracted area of prominent gamma-ray energy, by the relation (1) as mentioned by [12]:

$$A_s = \frac{C_n}{\varepsilon \times I_\gamma \times T \times m} \quad (1)$$

Where: A_s: specific activity in (Bq/kg); C_n: net count rate under peak per second; I_γ: gamma-ray emission probability for each energy; T: time for counting (sec); m: mass of sample (kg). Also, the radiological hazards resulting from the exposure to radiation arising from ^{226}Ra, ^{232}Th and ^{40}K in sediments can be determined by the parameters such as radium equivalent activity (Ra_{eq}) by equation (2) as reported by [14].

$$Ra_{eq} = C_{Ra} + 1.43 \times C_{Th} + 0.07 \times C_K \quad (2)$$

Where: C_{Ra}, C_{Th} and C_K represents the specific activity (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K, respectively. Also, absorbed dose rate (D_R) at one meter above the ground surface was calculated by the formula (3) [15].

$$D_R = 0.461 \times C_{Ra} + 0.623 \times C_{Th} + 0.041 \times C_K \quad (3)$$

Also, the external hazard index (Hex) was investigated by equation (4) and the value for this parameter must not exceed the limit of unity for the acceptable level [14].

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

Statistical analysis

The obtained outcomes of the sediment samples were statistically analyzed using statistical program software (SPSS) Statistical Package of the Social

Sciences.

RESULTS

The activity concentrations of the naturally occurring radionuclides ^{226}Ra, ^{232}Th, ^{40}K and artificial nuclide Cs^{137} are shown in table 2. From this table, the values of specific activity for the ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs radionuclides ranged between the high value to the low value as followed (136 – 41.8, 63 – 29.6, 976 – 664.8, 6.2 – 2.6 Bq/kg). The highest activity concentration occurred in sediment at sample code (S9) for ^{40}K is 976 Bq/kg and for ^{232}Th is 63 Bq/kg also for ^{137}Cs is 6.2 Bq/kg. The highest concentration of ^{226}Ra is 136 Bq/kg was determined at sample (S8). A slight level of ^{137}Cs was appeared in some sediment samples such as S7, S9, S10, S11, and S12; which indicates to the artificial pollution. The mean values of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs levels were (86.015, 48.446, 764.661, and 4.08 Bq/kg) dry weight, respectively.

The radiological parameters were estimated and the obtained values were compared with internationally recommended safety limits to determine the radiation hazard from natural radioactivity associated with the sediments. The radium equivalent activity (Ra_{eq}), gamma dose rates (D_R) and external hazard indexes (H_{ex}) were calculated from the measured activities of ^{226}Ra, ^{232}Th, ^{40}K and the results are given in table 3. The value of (Ra_{eq}) in the present study ranged from130.66 Bq/kg found in (S1) sample to 269.15 Bq/kg found in (S6) sample with a mean value of 211.3 Bq/kg which is less than the recommended maximum value of 370 Bq/kg. It was found that all (Reaq) values in the studied samples are lower than the standard limit of 370 Bq/kg. Absorbed gamma dose rate (D_R) ranged from 65 nGy/h in the (S1) sample to 114.5 nGy/h (S6) sample with an average value of 100.9 nGy/h. It is evident that the mean value of the rate of absorbed dose in the studied area is higher than the global limit of 55 nGy/h [14]. As regarded to the external hazard index (H_{ex}) the values of this indicators varied from 0.36 Bq/kg in (S1) sample to 0.72 Bq/kg (S8) sample with the average value 0.56 Bq/kg where this value is lower than permissible limit H_{ex} <1 [12]. That means the studies sediments samples may not be detrimental to the population in this area.

Table 2. Specific activity of radionuclides (Bq/kg) in sediment samples of the Euphrates River.

Sample code	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
S1	41.8 ± 8.7	29.6 ± 6.5	664.8±63.5	------
S2	51.2 ± 10	49.8 ± 9.9	765.8 ± 70	------
S3	113.4 ± 27	61.2 ± 15	806 ± 66	------
S4	78.2 ± 18	40 ± 11.3	667.6 ± 73	------
S5	107.4 ± 25	52 ± 11	737.4 ± 29	------
S6	104 ± 22	50 ± 8	868 ± 59	2.6 ± 0.7
S7	106 ± 22	46 ± 9	702 ± 88	------
S8	136 ± 18	52.4 ± 1.2	785.2 ± 86	------
S9	75 ± 15.3	63 ± 12.9	976 ± 75	6.2 ± 1.5
S10	48.4± 10.5	47.4 ± 12	780.8 ± 69	3.2 ± 0.9
S11	59.6 ± 9	41 ± 9	743 ± 66	3.6 ± 0.9
S12	119.2 ± 33	41.4 ± 7.2	674 ± 49	4.8 ± 1.2
S13	78 ± 12	56 ± 13	770 ± 59	------
Mean ± SD	86.015±8.6	48.446±7.4	764.661±45	4.08 ± 1.3

Table 3. Radiological hazards of sediment samples in the Euphrates River

Sample code	Ra_{eq} (Bq/kg)	D_R (nGy/h)	H_{ex} (Bq/kg)
S1	130.66	65	0.36
S2	176.02	85.8	0.49
S3	257.33	123	0.71
S4	182.13	88	0.5
S5	233.37	111.8	0.65
S6	269.15	114.5	0.67
S7	220.92	106	0.61
S8	265.89	127	0.72
S9	233.14	113.5	0.46
S10	170.83	83.7	0.47
S11	170.24	83.4	0.47
S12	225.58	108	0.6
S13	211.98	102	0.39
Mean ± SD	211.3 ± 10.7	100.9 ± 8.4	0.56 ± 0.01
global limits	370	55	< 1

DISCUSSION

The outcomes of ^{226}Ra, ^{232}Th, and ^{40}K levels varied from one site to another due to the presence of radionuclides in the marine environment depending on their physical, chemical, and geochemical properties. The low levels of ^{137}Cs were found in different locations that may be due to the fertilized soil in the investigated area or as a result of the Chernobyl accident events [12, 13]. The highest amount of ^{40}K dominates in the studied samples over the other isotopes because it is highly abundant in continental rocks and contains many light metals. This may be due to stream formations and potassium fertilizers washed by runoff into the river during the rainy season [5, 12].

On other hand, the figures of radium equivalent and external hazard index were lower than perm issible limits which indicate no high radiation health risks for people who live in the terrestrial areas adjacent to the sampling sites and people who deal with river sediments for use in the process of building houses from clay.

Table 4 shows the comparison of a particular activity in sediment samples and other studies. The content of ^{226}Ra in the present study is higher than that of other locations [15 – 23]. While ^{232}Th contents are low relative to the other researchers [15, 20] and higher than the other locations. As regarded to ^{40}K in the current study is lower than the results of Turkey [15], and higher than the other studies [16 – 23]. Also in this study, ^{137}Cs level is lower than that in Turkey (Van Lake Basin and Izmit Bay) [15, 22]; and higher than that in Ghana, Tema harbor [19]. From the results

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it is clear that the average values of ^{226}Ra, ^{232}Th and ^{40}K concentrations are higher when compared with worldwide average values [24].

Table 4. Comparison of activity concentration (Bq/kg) in sediment samples of the Euphrates River and other studies in different locations.

Location	Ra^{226}	Th^{232}	K^{40}	Cs^{137}	References
Turkey, Van Lake Basin	47.48	57.87	1021.4	4.37	(15)
Malaysia	51	22	189	-	(16)
USA, Reedy river	21.4	45.3	609	-	(17)
Egypt, Red Sea Coast	27.38	38.45	419.4	-	(18)
Ghana, Tema Harbor	14	30	325	1.5	(19)
Thailand, Battani Bay	4.9	55.8	183.2	-	(20)
Saudi Arabia, Persian Gulf	11.68	6.21	169.4	-	(21)
Turkey, Izmit Bay	18	-	568	21	(22)
Iraq, Maysan	-	13.79	317.34		(23)
Worldwide	33	45	420	-	(24)
Iraq , Al-Diwaniyah	86.015	48.446	764.661	4.08	[present study]

CONCLUSION

The results show that the concentrations of natural radionuclide activity in the sediment samples are higher than the permissible levels, since the nature of the area from which the samples were drawn is an agricultural area in which fertilizers are widely used during the cultivation of the land and the use of types of pesticides to protect agricultural crops from damage. Therefore, continuous monitoring of water quality is needed to record any change in the quality and reduce the prevalence of health problems and adverse effects on the aquatic ecosystem.

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Ethical consideration: Sediments samples were collected from Euphrates River in the study area. The results of the radiation hazards were within the safety levels, so these locations are considered safe and free of risks for the population.

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