Evaluation of Radioactivity Levels and Cancer Risk of Sediment Samples from the Euphrates River (AL-Diwaniyah Province, Iraq)

Kawthar Hassan Obayes

Department of Physics, College of Education, University of Al-Qadisiyah, Qadisiyah Governorate, Iraq
E-mail: kawthar.aljelehawy@qu.edu.iq (K.H.O.)
Manuscript received June 8, 2024; revised August 2, 2024; revised August 9, 2024; published November 26, 2024

***Abstract*—The levels of radionuclides of natural origin, represented by (^{238}U, ^{232}Th, ^{40}K), were evaluated for 15 samples from the surface sediments of the Euphrates River in the city of Diwaniyah in Al-Qadisiyah Governorate - Iraq. In this study, I am using gamma-ray spectroscopy with a sodium iodide detector NaI(Tl) to measure the concentrations of natural radionuclides ^{238}U, ^{232}Th, and ^{40}K in surface sediment samples and to evaluate the radioactive risks of these samples. The present study showed that the specific radioactivity rate of the sediment samples in units of (Bq/Kg) for isotopes (^{238}U, ^{232}Th, ^{40}K) were (17.3,15.5,302.3) Bq/Kg respectively. These values have been compared with some local and international studies, as well as with the global average recommended by the World Health Organization and UNSCEAR. The effects of radioactive hazards of gamma rays were also calculated for sediment samples. They were all less than the internationally permissible limit. according to these values, all the results of the current study are within the internationally permissible values mentioned in the reports of the international committees concerned with radiation and its protection, and this indicates that the sediments of the Euphrates River in the city of Diwaniyah-Qadisiyah Governorate do not have radioactive risks.**

***Keywords*—radionuclides, AL-Diwaniyah Province, NaI(Tl), Sediment, Euphrates River, Iraq**

I. Introduction

Man faces a great danger represented by his exposure to radioactive elements and the health risks caused by these elements that may have a significant impact on his life and may be reflected in future generations [1], so the environment is defined as a group of living elements, which are humans, animals, plants, microorganisms, and non-living elements It is the soil, air, and water that ensure the achievement of environmental balance [2].

Radioactive contamination is one of the most dangerous types of environmental pollution. As a result of exposure of body cells to radioactive materials, external and internal damage may lead to human life, Exposure to radiation from radioactive elements and their waste causes serious harm to humans and other living organisms, including anemia, suppression of the body's immune system, cancer, infertility, mutations in genetic genes, and congenital malformations of fetuses [3]. As for the natural radioactive activity in the sediments, it spreads widely and is found in most of the rocks and soils that make up the earth's crust in varying proportions. The concentration of natural radioactive isotopes in the sediments depends to a large extent on the type and nature of the composition of the soil components [4]. Rock weathering leaves behind sediments that retain the minerals that comprise the original rocks, reflecting the geological history of the transport and erosion process [5].

There has been a need to study the effect of radiation and to detect natural and industrial radioactivity to know the extent of environmental pollution and how to treat it. Numerous research studies have been carried out to determine the amounts of radioactive elements in soil, water, plants, air, and building materials to find out the extent of the impact of these radioactive materials on living organisms. The current study aims to calculate the concentrations of radionuclides (^{238}U, ^{232}Th, ^{40}K) in the sediments of the Euphrates River in the city of Diwaniyah - Qadisiyah Governorate - Iraq, using gamma spectroscopy technology, as well as calculating the radiation risks resulting from the concentrations of radionuclides in the Euphrates River (Shatt Al-Diwaniyah) and comparing these values with the permissible international limits and global and local studies. The study had to be conducted due to the environmental elements being affected by radiation and the environmental neglect that the city suffers from, to identify some aspects of the problem of the ongoing pollution of the Diwaniyah River and to contribute to developing some solutions.

II. Materials and Methods

A. Samples Collection

Al-Qadisiyah Governorate is one of the governorates of the Middle Euphrates region in Iraq, and a branch of the Euphrates River passes through it, known as (Shatt Al-Diwaniyah), as it is the longest watercourse that passes in the governorate, with a length of 123 km. Fifteen samples of surface sediment were collected from different locations along the Euphrates River in the city of Al-Diwaniyah - Al-Qadisiyah Governorate - Iraq. The studied area from which samples were collected is presented in Fig. 1, and Table 1 shows the coordinates of location samples for the present study.

B. Experimental Method

Fifteen samples of surface sediments were taken from the Euphrates River stream areas in the city of Diwaniyah - Qadisiyah Governorate - Iraq, where the sediment samples were withdrawn from a depth of 10 cm, and then the samples were placed in 1 kg plastic bags and the samples were marked with special codes, and a reading of the location was taken using a GPS device, then they were dried by exposing them to sunlight for 4 days to ensure that the samples were dehydrated, Then the samples were ground using an electric mill to obtain a fine powder, then a sieve with holes of 75 µm in diameter was used to obtain homogeneous samples, 1 kg of dried sediment was placed in a Marnelle container, and the mouth of the container was tightly closed to prevent the leakage of radioactive gases such as radon (^{222}Rn) and thoron (^{220}Rn), and left for a month to obtain a state of secular radioactive equilibrium [6].

Fig 1. Map of Iraq showing the location of Al-Qadisiyah governorate.

Table 1. Coordinates of location samples for the present study.

Sample code	Coordinates	
	Latitude (N)	Longitude (E)
S1	32°1′17.058"	44°49′41.6712"
S2	32°1′16.2048"	44°49′58.7856"
S3	32°1′3.0972"	44°50′13.4052"
S4	32°0′56.4696"	44°50′30.4008"
S5	32°1′2.3412"	44°50′58.3188"
S6	32°1′5.7324"	44°51′17.4888"
S7	32°0′56.61"	44°51′34.2036"
S8	32°0′35.1144"	44°51′41.7132"
S9	32°0′31.5972"	44°51′49.734"
S10	32°0′42.8832"	44°52′8.7996"
S11	32°0′41.724"	44°52′51.3768"
S12	32°1′9.5052"	44°52′57.6696"
S13	31°53′5.7192"	44°57′2.988"
S14	31°51′46.3644"	44°56′2.0616"
S15	31°51′5.4756"	44°56′8.9304"

C. Gamma-ray spectrometer

Using and outfitting electronic counting and analysis system for the detection of nuclear radiation equipped by the company (Alpha Spectra, Inc.-12I12/3), which consists of a NaI (Tl) scintillation detector with crystal dimensions of "3 × 3" and a multi-channel analyzer (MCA)(ORTEC - Digi Base) contains 4096 channels, as well as a unit that converts the main amplifier's pulse into digital numbers and then sends the spectral data directly to the personal computer [7]. To lessen background radiation, the detector was kept vertical and shielded by an ORTEC cylindrical chamber. IAEA radioactive sources (model RSS-8) containing ^{137}C, ^{54}Mn, ^{60}Co, ^{22}Na, and ^{152}Eu were employed as the energy and efficiency calibration sources for the detector to calibrate the NaI(Tl) detector. The working current accuracy value was 7.9% for a standard ^{137}C source with an energy of 661.66 keV.

D. Calculations

Using the NaI (Tl) detector and a computer program, with a collection time of (7200 sec), the radionuclides were identified according to their energy In the spectrum, then the Net Area was calculated for each radionuclide, after which the specific activity was estimated through the Eq. (1) [8]:

$$A\left(\frac{Bq}{Kg}\right) = \frac{N}{\varepsilon_\gamma \times I_\gamma \times T \times m} \quad (1)$$

where A is a specific activity in Bq/Kg, N is the net count under the top, ε_γ is the counting efficiency of the scintillator detector, I_γ is the percentage of the probability of gamma emission from a radionuclide, m is the mass of the sample in Kg, *t* is measurement time 7200 sec.

Using Eq. (2), the equivalent radium activity was calculated [9]:

$$Ra_{eq}\left(\frac{Bq}{Kg}\right) = A_U + 1.43\, A_{Th} + 0.077\, A_K \quad (2)$$

Since A_u, A_{Th}, and A_K are the radioactivity of the nuclides ^{238}U, ^{232}Th, and ^{40}K, respectively.

To determine the gamma-ray danger levels linked to naturally occurring radionuclides in the examined samples, the radioactivity coefficient was computed using the Eq. (3) [10]:

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (3)$$

The following Eqs. (4–8) give the internal and external hazard index (H_{ex}, H_{in}), the air-absorbed dose rate (D_γ), and the annual effective dose rate (AEDE) for the samples examined [11–13]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \quad (4)$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \quad (5)$$

$$D_\gamma\left(\frac{nGy}{h}\right) = 0.462\, A_U + 0.604\, A_{Th} + 0.0417 A_K \quad (6)$$

$$AEDE_{out\,door}\ (\mu Sv/y) = D_\gamma \times 8760 \times 0.2 \times 0.7 \quad (7)$$

$$AEDE_{In\,door}\ (\mu Sv/y) = D_\gamma \times 8760 \times 0.8 \times 0.7 \quad (8)$$

As for the following Eqs. (9–11), the equivalent annual dose of gonadotropins (AGDE) and the lifetime risk of cancer (ELCR) were estimated [14, 15]:

$$AGDE\left(\frac{\mu Sv}{y}\right) = 3.09\, A_U + 4.18\, A_{Th} + 0.314 A_K \quad (9)$$

$$ELCR_{out} = AEDE_{out\,door} \times DL \times RF \quad (10)$$

$$ELCR_{in} = AEDE_{in\,door} \times DL \times RF \quad (11)$$

where DL is the life span (70 years) and the risk factor (0.05 / Sv), respectively.

III. Result and Discussion

Sediment samples from the Euphrates River in AL-Diwaniyah province, Iraq, were analyzed both quantitatively and qualitatively was carried out using the sodium iodide detector NaI(Tl). The specific effectiveness of the radionuclides ^{238}U, ^{232}Th, ^{40}K was calculated, where the specific effectiveness of the isotope (^{214}Bi) at energy (609 keV) and the isotope (^{214}Pb) at energy (351 keV) were adopted as equivalent to the specific effectiveness of (^{238}U) by choosing the most valuable activity, the specific activity of the isotope (^{228}Ac) at energy (911 keV) was equivalent to the specific activity of (^{232}Th), The specific activity of ^{40}K was also adopted at the energy of 1460 keV. Table 2 shows the radioactivity concentrations of the main radionuclides emitting gamma rays of the series (^{238}U, ^{232}Th, ^{40}K) in sediment samples, Tables 3 and 4 show the radiological risks in sedimentary samples.

Table 2. Specific effectiveness of (^{238}U, ^{232}Th, ^{40}K) in the sediment samples of the Euphrates River in the city of Diwaniyah

Sample Code	U-238	Th-232	K-40
S1	16.6±0.98	13.6±0.87	300.7±16.5
S2	12.2±0.82	13.2±0.86	290.6±16.3
S3	10.3±0,72	11.6±0.79	261.4±15.9
S4	10.5±0.73	18.7±1.05	59.9±6.8
S5	14.8±0.92	4.8±0.32	362.1±17.2
S6	13.6±0.87	10.0±0.73	377.7±17.8
S7	15.4±0.95	12.1±0.82	236.9±14.5
S8	22.7±1.13	20.8±1.10	127.4±12.8
S9	18.8±1,05	15.3±0.94	233.6±14.3
S10	20.5±1.10	18.7±1.04	399.6±19.4
S11	21.6±1.12	20.6±1.09	364.2±17.3
S12	17.9±1.00	15.1±0.93	356.2±17.0
S13	23.9±1.14	21.5±1.11	400.3±19.5
S14	22.1±1.13	20.9±1.10	396±19.1
S15	19.5±1.08	16.7±0.98	368.3±17.5
Average	17.3±0.99	15.5±0.95	302.3±16.7
Worldwide [16]	2	25	370

Table 3. The radiation hazard indicators represented by (R_{eq}, I_γ, H_{ex}, H_{in}, D_γ) in the studied samples

Sample Code	R_{eq} (Bq/kg)	I_γ	H_{ex}	H_{in}	D_γ (nGy/h)
S1	59.2	0.446	0.159	0.204	28.4
S2	53.4	0.406	0.144	0.177	25.7
S3	47.0	0.358	0.126	0.154	22.6
S4	41.8	0.296	0.113	0.141	18.6
S5	49.5	0.387	0.133	0.173	24.8
S6	56.9	0.442	0.153	0.190	28.0
S7	50.9	0.381	0.137	0.179	24.3
S8	62.2	0.444	0.168	0.229	28.3
S9	58.6	0.433	0.158	0.209	27.6
S10	78.0	0.589	0.210	0.266	37.4
S11	79.1	0.592	0.213	0.272	37.6
S12	66.9	0.507	0.180	0.229	32.2
S13	85.4	0.640	0.230	0.295	40.7
S14	82.4	0.619	0.222	0.282	39.3
S15	71.7	0.542	0.193	0.246	34.4
Average	62.9	0.472	0.169	0.216	30.0
Worldwide [16]	370	1	≤ 1	≤ 1	84

Table 4. The radiation hazard indicators represented by (AEDE, AGDE, ELCR) in the studied samples

Sample Code	$AEDE_{out}$ ($\mu Sv/y$)	$AEDE_{in}$ ($\mu Sv/y$)	AGDE ($\mu Sv/y$)	$ELCR_{out}$ × 10−3	$ELCR_{in}$ × 10−3	ELCR × 10−3
S1	3.48	13.9	202.5	0.0122	0.0488	0.0610
S2	3.15	12.6	184.1	0.0110	0.0441	0.0552
S3	2.77	11.1	162.3	0.0097	0.0389	0.0486
S4	2.28	9.1	129.4	0.0080	0.0320	0.0400
S5	3.04	12.1	179.4	0.0106	0.0426	0.0533
S6	3.44	13.7	202.4	0.0120	0.0482	0.0602
S7	2.98	11.9	172.5	0.0104	0.0417	0.0521
S8	3.47	13.9	197.0	0.0121	0.0486	0.0608
S9	3.39	13.5	195.3	0.0118	0.0475	0.0593
S10	4.59	18.3	266.9	0.0160	0.0642	0.0803
S11	4.61	18.4	267.2	0.0161	0.0645	0.0807
S12	3.95	15.8	230.2	0.0138	0.0553	0.0692
S13	4.99	19.9	289.4	0.0174	0.0699	0.0873
S14	4.82	19.3	279.9	0.0168	0.0675	0.0844
S15	4.22	16.9	245.7	0.0147	0.0591	0.0739
average	3.68	14.7	213.6	0.0128	0.0515	0.0644
Worldwide [16]	70	450	1000	0.29	1.16	1.45

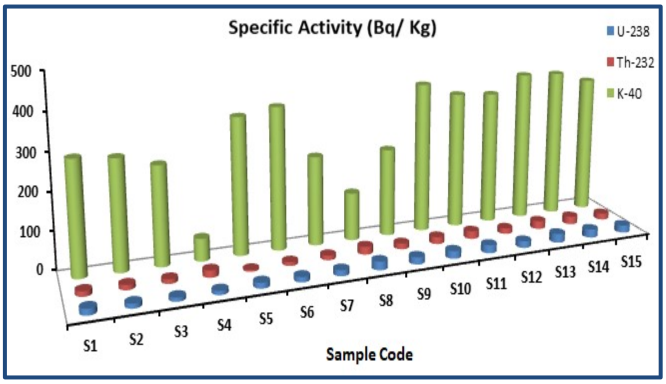

Fig. 2. Activity of U-238, Th-232, and K-40 in sediment samples.

From the results, it was found that the average concentration of (^{238}U, ^{232}Th, ^{40}K) is (17.3, 15.5, 302.3) Bq /Kg respectively, while the global average concentration of radionuclides for (^{238}U, ^{232}Th, ^{40}K) is (25,25,370) Bq/Kg respectively [16]. The results of the current study show that the average concentrations of radioactivity of these radionuclides in sediment samples are lower than their global concentration according to the UNSCEAR report [16], as shown in Fig. 2.

The results of the current study also showed that all radiation risk values represented by (**R_{eq}, I_γ, H_{ex}, H_{in}, D_γ, $AEDE_{out}$, $AEDE_{in}$, AGDE, $ELCR_{out}$, $ELCR_{in}$, ELCR**) were less than the internationally accepted limit according to the UNSCEAR report. Table 5, and Fig. 3 show a comparison of the specific activity concentration of natural radionuclides in a unit (Bq / Kg) in the sediment samples of the current study with other studies around the world.

Table 5. comparison of the specific activity concentration of natural radionuclides in a unit (Bq / Kg) in the sediment samples of the current study with other studies around the world

Location	U-238	Th-232	K-40	References
Maysan / Iraq	18.220	13.792	317.343	[17]
Najaf / Iraq	5.977	0.700	378.161	[18]
Karbala / Iraq	80.609	40.053	374.955	[19]
Babylon / Iraq	24.558	5.653	200.865	[20]
Turkey	47.48	57.87	102.4	[21]
Egypt	27.38	38.45	419.4	[22]
Worldwide[16]	25	25	370	[16]
Present study	17.3	15.5	302.3	

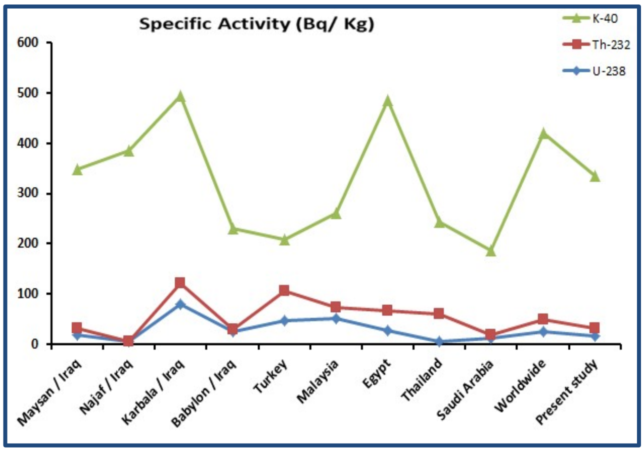

Fig. 3. Comparison of the concentration of specific activity in sediment samples of the current study with other studies around the world.

IV. Conclusion

In the current study, 15 samples were collected from the surface sediments of the Euphrates River in the city of Al-Diwaniyah in Al-Qadisiyah Governorate - Iraq. The results obtained from gamma-ray spectroscopy analysis of NaI(Tl) showed that the radioactivity concentrations of natural radionuclides ^{238}U and ^{232}Th were all less than the Internationally permitted range. We believe that the absence of high levels of specific activity of ^{238}U, ^{232}Th in the sediment samples is due to the geological formation of the region and the absence of radioactive activities that contribute to raising the levels of radioactive background in the region. It was found that the specific activity of ^{40}K in some sediment samples was higher than the permissible limit globally. The reason is due to The presence of agricultural lands containing phosphate fertilizers in which the concentration of potassium isotope increases. As for the radiation hazard indicators, all values were less than The global rate recommended by the World Health Organization and UNSCEAR, so it does not pose a threat to the population in or near these locations, but its accumulation could hurt public health. I recommend conducting periodic radiation scans to monitor radiation changes in the governorate.

Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Kawthar Hassan Abbas conducted the entire research, including collecting samples, preparing them for measurement, using the detector to obtain the spectrum, calculating the results, discussing them, and writing the paper.

Acknowledgment

I would like to thank the Department of Environment in the city of Diwaniyah for providing administrative facilities in implementing this study. I also thank the College of Science, University of Kufa, and the Department of Physics for helping me use the detector and conduct statistical analysis of the studied samples. I would also like to point out that the current study is self-financing by the researcher only and there is no external support.

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