Radiological Risk Assessment and Radioactivity Concentration in sediment of Tigris River of the Medical City/Bab Al Muadham

Athraa Naji Jameel

athraanaje@uommustansiriyah.edu.iq

Department of Physics, College of Education, Mustansiriyah University, Baghdad, Iraq

Article history: Received, 7, November, 2021, Accepted 19, December, 2021, Published in January 2022.

Doi: 10.30526/35.1.2796

Abstract

The concentrations of natural radionuclides in sediment samples from various locations along the stream of the Tigris riverbank in the Medical city in Bab Al- Muadham, Baghdad, had been examined using NaI(Tl) detector. The mean concentrations of specific activity for $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs for sediments of the river was 13.5±4.6, 35.2±3.1, 272.2±21.4 and 1.5±0.35 Bq/kg respectively. The findings revealed that the concentration values of natural radionuclides and cesium were below permitted limits. The radiological hazard was compared with a global average (Radium equivalent, absorbed dose rate, radiation hazard index and annual effective dose equivalent) finding it was less than reported by UNSCEAR. The radium equivalent activity was 102.22 Bq/kg and the maximum absorbed dose rate was 88.1 nGy/h. At the same time, the mean annual effective dose equivalent was 420.1 µSv/y. The highest risk index was 0.39 and is much less than 1, except for the lifetime cancer risk were valuing between 164.2×10$^{-3}$ to 1620×10$^{-3}$. This is a higher value than the global average.

Keywords: Sediments, Tigris River, radiological hazards, gamma-ray spectrometry, Bab Al Muadham.

1. Introduction

Since the middle of the twentieth century, radiological pollution has been one of the most critical worldwide environmental issues that have occupied the attention of world governments[1]. Serious trends are represented in the great diversity and the emergence of some industrial complex, which is often accompanied by serious pollution that leads to the degradation of the ocean Biodynamic and erratic global environment. Furthermore, as the use of sources and isotopes of radiation expands in various aspects of human existence, for peaceful or military goals, the risk of radioactive contamination rises[2-4].

Sediments had an active role in hydrous radioecology; Soil and rocks are the key supply of radiation exposure to the population and additionally a way of radionuclide migration into
the surroundings [5,6]. Sediments are a significant source of radiation exposure to aquatic biota, and it acts as a medium of migration for the transfer of radionuclides within the aquatic environment.

The sediment deposited at the lowest of rivers most often encompasses sand and gravel of various grain sizes, terribly valuable for building constructions [7,8]. Sediment can have a total body effect due to external radiation originating directly from primordial radionuclides contained in sediment, or it can have an interior effect due to radon inhalation [9].

2. Materials and methods

2.1 Sample Collection and Preparation

Fourteen sediment samples have been collected from diverse places alongside the river bank. Sample collection was at a depth of four cm alongside the Tigris river around Medical City in Bab Al-Muadham were examined to estimate the natural radioactivity level. Then, the samples were place after collection in Plastic bags. The samples had been oven-dried at a temperature of 120 °C for four hours, then the grinding and sieving process. All sediment samples had been weighed and sealed in Marinelli containers. The samples had been sealed hermetically and stored for about four weeks to reach secular equilibrium.

2.2 Radioactivity measurement

Samples have measurement with gamma spectrometry method the use of 3×3 inch NaI(Tl) detector, Alpha Spectra Inc., Made in USA. The detector has a relative performance of 90% and a power of 28.74 KeV at a $^{60}$Co gamma ray energy of 1332 KeV. A specialized computer program can control this analyzer (bMCA). The Analyzer with multiple channels. It studies and analyses the gamma spectrum of gamma rays. It has a red light indicator for intermittent gamma-rays to the detector, and it is connected to a computer via USB cable to send the signal to the bMCA program. The consists of radionuclides and includes all of $^{241}$Am (59.5KeV), $^{60}$Co (1173.24 and 1332.50 KeV), $^{137}$Cs 661.66 KeV). To measure the radiological background, the activity of $^{238}$U was given through the Gamma line of its product decay $^{214}$Bi (1764.5 KeV). The activity of $^{232}$Th was provided by the product of $^{208}$Tl (583.19 and 2614.5 KeV). The concentrations of $^{40}$K and $^{137}$Cs were determined by calculating their gamma Energy lines, 1460.8 KeV and 661.61 KeV, respectively.

3. Calculations

3.1. Specific activity

The levels of radioactivity for radium, thorium, and potassium are calculated according to the equation [10]:

$$ A(t) = \frac{N}{\varepsilon(E_{\gamma}) \times I(E_{\gamma}) \times m \times t} \quad (1) $$

Where N: Net counts, $\varepsilon(E_{\gamma})$ is the detector efficiency $I(E_{\gamma})$: the abundance of energy, t: Time for data collection, m is the mass of samples.
3.2 Radium equivalent activity
The specific activity concentration level of components which includes $^{286}$Ra, $^{232}$Th, and $^{40}$K use of the equation [11].

$$R_{aeq} = A_{Ra} + 1.43 \times A_{Th} + 0.077 \times A_{K} \quad (2)$$

3.3. Absorbed dose rate
The following equations are used to calculate the indoor and outdoor absorbed dose rates [12,13].

$$D_{out} (nGy/h) = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_{K} \quad (3)$$

$$D_{in}(nGy/h) = 0.92 A_{Ra} + 0.081 A_{K} + 1.1 A_{Th} \quad (4)$$

Where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activity concentrations in ($Bq/kg$) of uranium, thorium and potassium respectively.

3.4. Annual effective dose equivalent
The annual effective dose equivalent rate is calculated, which considering the conversion coefficient from the absorbed dose inside the air (0.7 Sv/Gy) and the outdoor occupancy factor (0.2). Therefore, the annual effective dose equivalent rates in mSv/y are calculated via the following formulation [14]:

$$A_{EDE_{out}} = D_{out} (nGy/h) \times 0.7(Sv/Gy) \times 8760(h/y) \times 0.20 \times 10^{-3} \quad (5)$$

$$A_{EDE_{in}} = D_{in}(nGy/h) \times 0.7(Sv/Gy) \times 8760(h/y) \times 0.80 \times 10^{-3} \quad (6)$$

3.5 Hazard index
The outside and inner hazard index is used for the assessment of outside exposure to gamma radiation. The equations can be used to compute the outdoor and the indoor hazard index [15,16]:

$$H_{ex} = \frac{A_{U}}{370 \text{ Bq/kg}} + \frac{A_{Th}}{259 \text{ Bq/kg}} + \frac{A_{K}}{4810 \text{ Bq/kg}} \quad (7)$$

$$H_{in} = \frac{A_{U}}{185 \text{ Bq/kg}} + \frac{A_{Th}}{259 \text{ Bq/kg}} + \frac{A_{K}}{4810 \text{ Bq/kg}} \quad (8)$$

3.6. Extra Lifetime cancer risk (ELCR)
Radionuclides may be envisioned in terms of extra lifetime cancers danger. It calculates the use of the equation [17,18].

$$ELCR_{out} = A_{EDE_{out}} \times DL \times RF \quad (9)$$

$$ELCR_{in} = A_{EDE_{in}} \times DL \times RF \quad (10)$$

Where AEDE is the annual effective dose equivalent, DL isthe duration of life (70yrs),and RF is the risk factor (0.05 Sv$^{-1}$). For stochastic effects, ICRP 60 uses of 0.05/Sv.
Ibn Al-Haitham Jour. for Pure & Appl. Sci. 35(1)2022

4. Results and Discussion

Table (1) shows specific activity concentrations of the samples collected from the sediment of the Tigris river region, the activity concentration of $^{238}$U range from 9.7 to 18.5 Bq/kg with a mean value 13.5±4.6 Bq/kg and from 24.33 to 54.00 Bq/kg for $^{232}$Th with mean value 35.2±3.1 Bq/kg. The concentration for $^{40}$K range from 173.44 to 370.7 with a mean value 272.2±21.4 Bq/kg and 0.066 to 1.99 Bq/kg with a mean value of 1.5±0.35 Bq/kg for $^{137}$Cs as shown in Figure 1. The variation of values in The radionuclide activity concentration and radioactivity coefficients in sediments are determined by particle size, pH, and waste from hospitals and industrial dumped in rivers.

Regarding the activity concentration of natural radionuclides and $^{137}$Cs for the sediment of Tigris river samples were Within the permissible limits as reported by UNSCEAR, 2010.

Table 1. Specific activity concentrations of $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs in samples sediment of Tigris river.

| Codes | Specific activity concentration (Bq/kg) | $^{40}$K | $^{238}$U | $^{232}$Th | $^{137}$Cs |
|-------|----------------------------------------|-------|--------|---------|---------|
|       |                                        | $^{226}$Ra | $^{214}$Pb | $^{214}$Bi |         |
| S1    | 298.87                                 | 9.8   | 4.960  | 6.55    | 42.50  | 1.179 |
| S2    | 173.44                                 | 9.7   | 3.20   | 3.1     | 24.33  | 0.13  |
| S3    | 212.76                                 | 14.457| 5.071  | 7.52    | 43.33  | 0.066 |
| S4    | 218.92                                 | 14.33 | 4.007  | 7.71    | 25.79  | 0.23  |
| S5    | 233.64                                 | 8.45  | 5.996  | 3.81    | 30.98  | 1.80  |
| S6    | 207.45                                 | 14.67 | 3.409  | 4.39    | 33.00  | 1.04  |
| S7    | 278.37                                 | 16.30 | 6.123  | 7.62    | 44.79  | 1.894 |
| S8    | 215.37                                 | 16.8  | 6.44   | 4.34    | 38.04  | 1.00  |
| S9    | 370.7                                  | 18.5  | 12.44  | 14.1    | 54.00  | 1.99  |
| S10   | 245.5                                  | 10.98 | 5.33   | 3.51    | 46.00  | 1.33  |
| S11   | 298.38                                 | 12.00 | 4.55   | 6.68    | 43.68  | 1.008 |
| S12   | 120.64                                 | 9.77  | 4.44   | 3.4     | 35.18  | 1.00  |
| S13   | 220.33                                 | 14.6  | 9.54   | 5.12    | 28.0   | 1.00  |
| S14   | 345                                    | 12.5  | 12.5   | 3.71    | 25     | 1.44  |
| Average| 272.2±                                 | 13.5± | 17.6±  | 6.21±   | 35.2±  | 1.5±  |
|       | 21.4                                   | 4.6   | 4.7    | 0.81    | 3.1    | 0.35  |

Limit UNSCEAR,[19] | 400 | 33 | 45 | 2 [20] |
Tables 2 and 3 shows the calculated results of radiation hazard indices (radium equivalent activity, absorbed dose rate, annual effective dose equivalent, hazard index, and Lifetime cancer risk) for all samples. All of the radiation risk indices have values below the allowed limits. The computed values for radium equivalent activities are shown in Figure 2, where it turns out that values ranged 48.778 Bq/kg in sample 12 to 102.22 Bq/kg in sample 9 with a mean value 79.01± 2.24 Bq/kg in Tigris river sediment samples.

The values obtained of the outside, absorbed dose rate in the sampled sediment of Tigris river various from 22.653 nGy/h to 54.12 nGy/h. While, inside absorbed dose rate ranged from 47.749 nGy/h to 88.1 nGy/h, The highest absorbed dose rate outside and inside the body became recorded in sample 9. While the lowest values are in sample 4 as shown in Figure 3.

The results of annual effective dose in the sediment samples. The highest concentration within the annual effective dose outside and inside the body is 420.1to 55.3 μSv/y that is sample 9. The lowest the annual effective dose outside and inside the body was 272.783 to 41.234 μSv/y of sample 2 as shown in Figure 4.
Table 2. Radium equivalent activity, Absorbed dose rate and Annual effective dose equivalent of samples from Tigris river.

| Code | $Ra_{eq}$ (Bq/kg) | $D$(nGy/h) inside | $D$(nGy/h) Outside | ADED(μSv/y) inside | ADED(μSv/y) Outside |
|------|-------------------|-------------------|-------------------|-------------------|-------------------|
| S1   | 89.161            | 76.403            | 41.32             | 373.747           | 50.543            |
| S2   | 59.993            | 47.749            | 31.145            | 272.783           | 41.234            |
| S3   | 87.984            | 73.765            | 40.085            | 361.862           | 49.16             |
| S4   | 59.796            | 50.789            | 22.653            | 258               | 37.782            |
| S5   | 72.117            | 62.042            | 33.357            | 304.353           | 40.909            |
| S6   | 69.663            | 59.083            | 32.001            | 289.838           | 40.246            |
| S7   | 95.521            | 80.058            | 30.376            | 295.904           | 53.253            |
| S8   | 77.919            | 65.52             | 35.577            | 321.415           | 43.632            |
| S9   | 102.22            | 88.1              | 54.12             | 420.1             | 55.3              |
| S10  | 87.34             | 73.576            | 39.978            | 360.934           | 49.029            |
| S11  | 86.071            | 79.783            | 39.109            | 352.139           | 47.963            |
| S12  | 48.778            | 53.8              | 29.5              | 290.97            | 39.479            |
| S13  | 76.2              | 60.2              | 34.11             | 315.5             | 42.1              |
| S14  | 71.568            | 63.958            | 33.945            | 313.752           | 41.63             |
| Average | 79.01          | 66.34             | 36.158            | 329.25            | 44.44             |
| ±2.24 | ±1.96          | ±0.98             | ±7.98             | ±16.1             |

Limit[19] 370 84 290 [21]

Figure 2. Radium equivalent activity in samples sediment of Tigris river.
Table 3 and Figures 5, 6 explain the hazard index and Extra lifetime cancer risk in Sediment samples. The highest external hazard index value was 0.33 Bq/kg in sample 9, but the highest value was 0.39 Bq/kg in internal. In contrast, the lowest value sample 4. The highest value and the lifetime risk of cancer in the body, is found in the sample 1 but the highest outside value in sample 7 in the Sediment samples of the Tigris river.
Table 3. Annual gonadal dose equivalent, Hazard index, and Extra Lifetime cancer risk in Sediment of Tigris river.

| Codes | Hazard index(Bq/kg) | ELCR(mSv/y) |
|-------|---------------------|-------------|
|       | $H_{\text{out}}$ | $H_{\text{in}}$ | Inside | Outside |
| S1    | 0.24                | 0.25        | 1370.115 | 177.901 |
| S2    | 0.178               | 0.231       | 912.241  | 109.319 |
| S3    | 0.238               | 0.264       | 1266.517 | 172.06  |
| S4    | 0.134               | 0.177       | 970.5    | 116.237 |
| S5    | 0.157               | 0.221       | 1065.236 | 143.182 |
| S6    | 0.188               | 0.226       | 1014.433 | 137.361 |
| S7    | 0.23                | 0.299       | 1385.664 | 186.386 |
| S8    | 0.21                | 0.232       | 1145.9   | 152.712 |
| S9    | 0.33                | 0.39        | 1620     | 164.2   |
| S10   | 0.236               | 0.255       | 1263.2   | 171.602 |
| S11   | 0.232               | 0.235       | 1232.48  | 185.871 |
| S12   | 0.213               | 0.20        | 924.89   | 126.677 |
| S13   | 0.173               | 0.33        | 1134.1   | 134.2   |
| S14   | 0.193               | 0.218       | 1098.13  | 145.705 |
| Average | 0.257±               | 0.265±       | 1181.41± | 153.138± |
|        | 0.040               | 0.019        | 29.19    | 5.2     |
| Limit[22] | 1                | 1.16 × 10^{-3} | 0.29 × 10^{-3} |

![Hazard Index Graph](image)
5. Conclusion

Radioactivity in sediment samples from various locations along the stream the Tigris riverbank stream in the Medical city in Bab Al- Muadham in Iraq, was using the NaI(Tl) gamma-ray spectrum detector measured. The mean activity concentration of $^{40}$K, $^{238}$U and $^{232}$Th is within the world average.

The radium-equivalent equivalent, annual effective dose rate, absorbed rate and risk indices are all estimated under the permissible limits. Still, the values lifetime cancer risk (ECLR) is above the worldwide average according to UNSCEAR. The results obtained show that there may be no health implication for the general populace, but prolonged exposure could lead to radiation related health hazard. Therefore, the government should monitor the release of environmental pollutants and industrial activities along the river.

Acknowledgments

The author would like to thank Mustansiriyah university (www.uomustansiriyah.edu.iq) in Baghdad –Iraq for its support in the present work.

References

1. Fathi, R. A.; Matti, L. Y.; Al-Salih, H. S.; Godbold, Environmental pollution by depleted uranium in Iraq with special reference to Mosul and possible effects on cancer and birth defect rates, *Medicine, conflict and survival*, 2013, 29, 1, 7-25.
2. Ajayi, J. O.; Adedokun, O.; Balogun, B. B., Levels of Radionuclide Content in stream water of some selected rivers in Ogbomosho land, *2012, 4, 9, 835-837.
3. Klaus, Becker.; How much protection against Radon do we need, *2001, 114,3, 24-29.
4. Durrani, Saeed. A., Richard, K. B.; Solid state nuclear track detection: principles, methods and applications, Elsevier, 2013,111.

5. Raja, Waleed N.; Measurement of radon concentrations in water around the northern areas of Baghdad using the CN-85 track detector, AIP Conference Proceedings. AIP Publishing LLC, 2019,020063.

6. Ajayi, I. R.; Background radioactivity in the sediments of some rivers and streams in Akoko, Southwestern, Nigeria and their radiological effects, Health Physics, 2011, 101,1.

7. Ononugbo, C. P., Avwiri, G. O., Ogan, C.A.; Natural radioactivity measurement and evaluation of radiological hazards in sediment of Imo River, in rivers state, Nigeria by gamma ray spectrometry. Journal Appl Phys, 2016, 8,3, 75-83.

8. Obed, R.I.; Farai, I.P.; Jibirji, N.N.; Population Dose Distribution due to Soil Radioactivity Concentration levels in 18 cities across Nigeria, Journal of Radioactivity Protection, 2005, 25, 3, 305.

9. Avwiri, G.O.; Ononugbo, C.P.; Nwokeoji, I. C.; Radiation Hazard Indices and Excess Lifetime cancer risk in soil, sediment and water around mini-okoro/oginigba creek, Port Harcourt, Rivers State, Nigeria. Comprehensive Journal of Environment and Earth Sciences, 2014, 3,1: 38-50.

10. Jameel, A. N.; Evaluation of the radiological hazard in some dried fruit and grain samples in Iraqi Markets by Using of gamma ray Spectroscopy, Journal of Physics: Conference Series. IOP Publishing, 2021, 1879, 3.

11. European Commission. Radiological protection principles concerning the natural radioactivity of building materials in EC radiation Protection 112 Directorate General Environment, UC, Nuclear Safety and Civil Protection, 1999.

12. Ionising Radiation: Sources, and Biological Effect United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations: New York: UNSCEAR, 1982.

13. Viruthagiri, G.; Ponnarasi, K., Advances in Applied Science Research,, 2011, 2, 2, 103-108.

14. Ridha, A. A.; Jameel, A. N., Kadhm, N. Farhan.; Transfer factor of natural radionuclides from soil to silhouette plants using gamma spectroscopy, AIP Conference Proceedings. AIP Publishing LLC, 2020, I, 2213.

15. Mamont-Ciesla, K.; Gwiazdowski, B.; Biernacka, M.; A Radioactivity of building materials in Poland. In G. Vohra, K. C. Pillai, and S. Sadavisan (Eds), Natural radiation environment, Halsted Press, 1982, 55.

16. Uosif, M.A.M.; Shams, Issa.; Elsaman, R.; Gamma Radioactivity Measurements in Nile River Sediment Samples, Turkish Journal of Engineering and Environmental Sciences, 2013.

17. Taskin, H., Karavus. M., Ay P., Topuzoglu, A., Hindiroglums, S. Karahan, G.; Radionuclide concentrations in soil lifetime cancer risk due to gamma radioactivity in Kirklaeli, turkey, Journal of Environmental Radioactivity, 2009, 100, 49-53.

18. Ramasamy, V.; Suresh, G.; Meenakshisundaram,V.; Gajendran,V.; Evaluation of natural radionuclide content in river sediments and excess lifetime cancer risk due to gamma radioactivity, Research journal of environmental and earth, 2009, 1, 1, 6-10.
19. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR, Report to the General Assembly, with Scientific Annexes United Nations, New York, 2010.

20. United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation, UNSCEAR, Report to the General Assembly, 1993.

21. Sources and Effects of Ionizing Radiation. New York: United Nations Publication, UNSCEAR, 2008, 223–233.

22. United Nations scientific committee on the effects of atomic radiation. Sources effects and risks of ionizing radiation. UNSCEAR, Report to the General Assembly, with Scientific Annexes Volume I: Sources, United Nations, New York, 2000.