



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

Athraa Naji Jameel

[athraanaje@uomustansiriyah.edu.iq](mailto:athraanaje@uomustansiriyah.edu.iq)

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

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### 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  $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  for sediments of the river was  $13.5\pm 4.6$ ,  $35.2\pm 3.1$ ,  $272.2\pm 21.4$  and  $1.5\pm 0.35$  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  $\mu\text{Sv/y}$ . The highest risk index was 0.39 and is much less than 1, except for the lifetime cancer risk were valuing between  $164.2\times 10^{-3}$  to  $1620\times 10^{-3}$ . 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 placed 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 <sup>60</sup>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 <sup>241</sup>Am (59.5KeV), <sup>60</sup>Co (1173.24 and 1332.50 KeV), (<sup>137</sup>Cs 661.66 KeV). To measure the radiological background, the activity of <sup>238</sup>U was given through the Gamma line of its product decay <sup>214</sup>Bi (1764.5 KeV). The activity of <sup>232</sup>Th was provided by the product of <sup>208</sup>Tl (583.19 and 2614.5 KeV). The concentrations of <sup>40</sup>K and <sup>137</sup>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  $^{286}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  use of the equation [11].

$$Ra_{eq} = A_{Ra} + 1.43 \times A_{Th} + 0.077 \times A_K \quad (2)$$

### 3.3. Absorbed dose rate

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

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

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

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]:

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

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

### 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].

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

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

Where AEDE is the annual effective dose equivalent, DL is the duration of life (70yrs), and RF is the risk factor (0.05 Sv<sup>-1</sup>). For stochastic effects, ICRP 60 uses of 0.05/Sv.

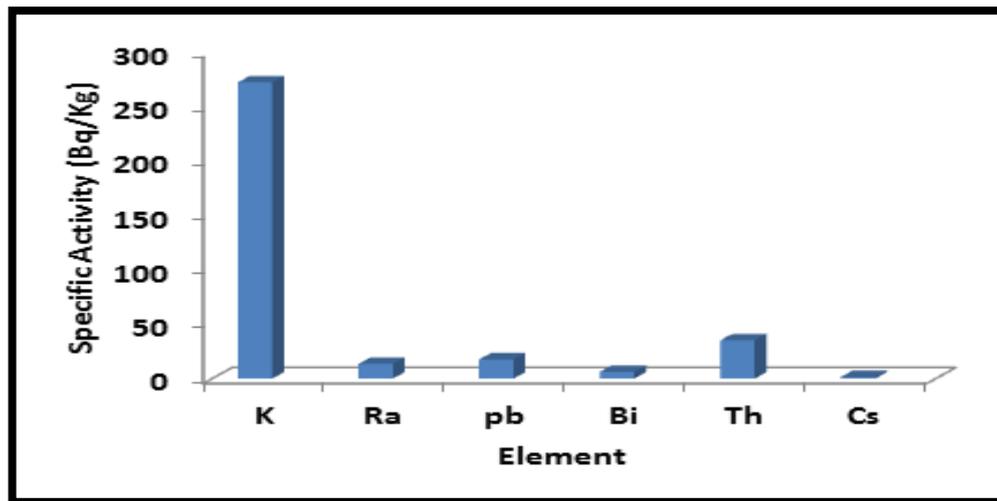
4. Results and Discussion

**Table (1)** shows specific activity concentrations of the samples collected from the sediment of the Tigris river region, the activity concentration of  $^{238}\text{U}$  range from 9.7 to 18.5 Bq/kg with a mean value  $13.5\pm 4.6$  Bq/kg and from 24.33 to 54.00 Bq/kg for  $^{232}\text{Th}$  with mean value  $35.2\pm 3.1$  Bq/kg. The concentration for  $^{40}\text{K}$  range from 173.44 to 370.7 with a mean value  $272.2\pm 21.4$  Bq/kg and 0.066 to 1.99 Bq/kg with a mean value of  $1.5\pm 0.35$  Bq/kg for  $^{137}\text{Cs}$  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  $^{137}\text{Cs}$  for the sediment of Tigris river samples were Within the permissible limits as reported by UNSCEAR, 2010.

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

Codes	Specific activity concentration (Bq/kg)					
	$^{40}\text{K}$	$^{238}\text{U}$			$^{232}\text{Th}$	$^{137}\text{Cs}$
		$^{226}\text{Ra}$	$^{214}\text{Pb}$	$^{214}\text{Bi}$		
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
<b>Average</b>	$272.2\pm 21.4$	$13.5\pm 4.6$	$17.6\pm 4.7$	$6.21\pm 0.81$	$35.2\pm 3.1$	$1.5\pm 0.35$
<b>Limit UNSCEAR,[19]</b>	<b>400</b>	<b>33</b>			<b>45</b>	<b>2 [20]</b>



**Figure 1.** Specific activity concentration in sample sediment of Tigris river.

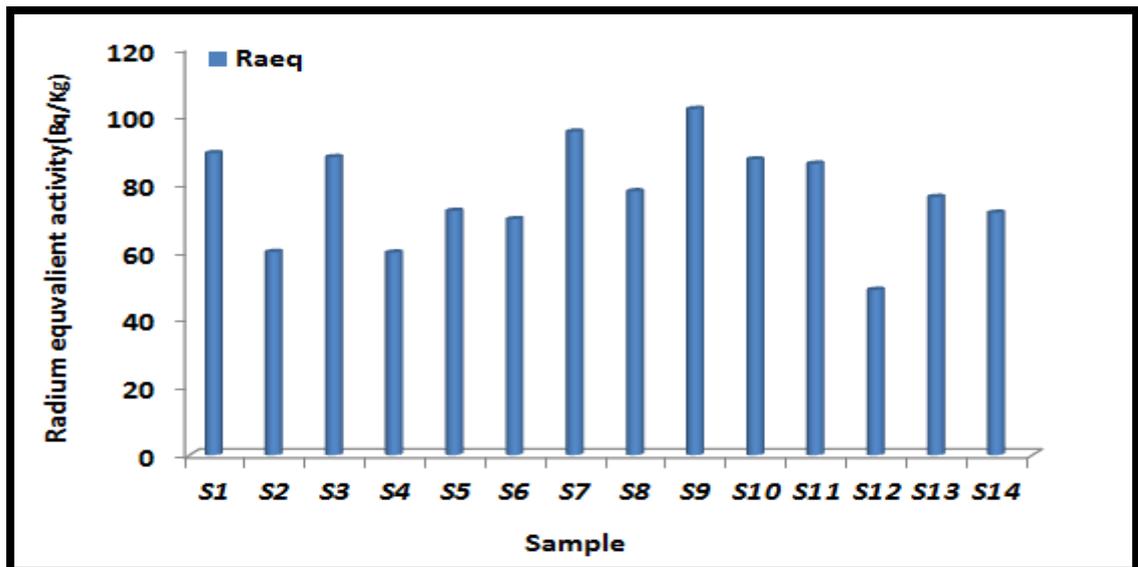
Tables 2 and 3 shows the calculated results of radiation hazard indices (radium equivalent activity, absorbed dose rate, annual effective dose equivalent, hazard index, and Lifetime cancer risk) for all samples. All of the radiation risk indices have values below the allowed limits. The computed values 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  $79.01 \pm 2.24$  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 420.1 to 55.3  $\mu$ Sv/y that is sample 9. The lowest the annual effective dose outside and inside the body was 272.783 to 41.234  $\mu$ Sv/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	R <sub>aeq</sub> (Bq/kg)	D(nGy/h)		ADED(μSv/y)	
		inside	Outside	inside	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
<b>Average</b>	79.01 ±2.24	66.34 ±1.96	36.158 ±0.98	329.25 ±7.98	44.44 ±16.1
<b>Limit[19]</b>	<b>370</b>	<b>84</b>		<b>290 [21]</b>	



**Figure 2.** Radium equivalent activity in samples sediment of Tigris river.

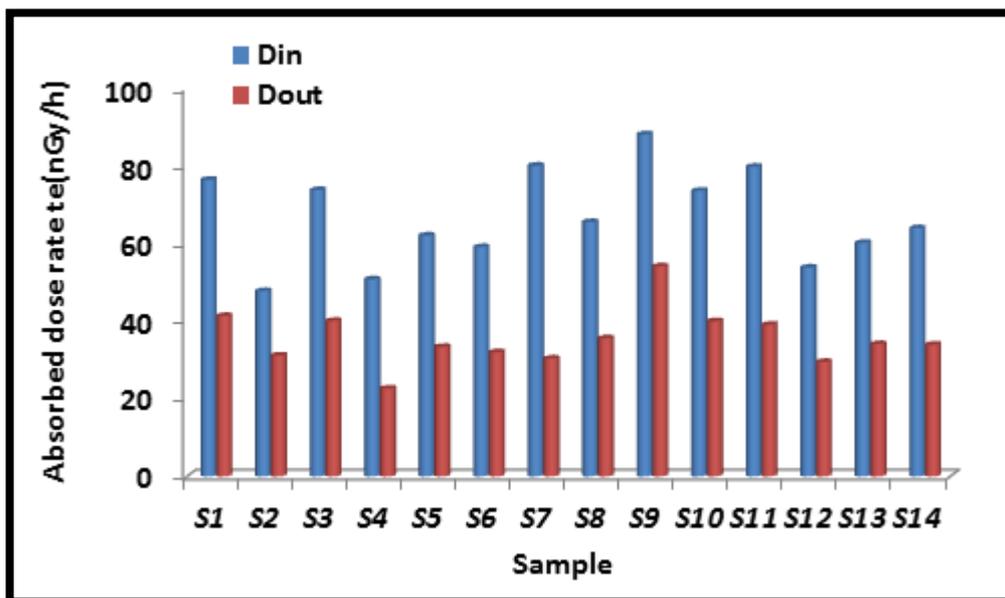


Figure 3. Absorbed dose rate in samples sediment of Tigris river.

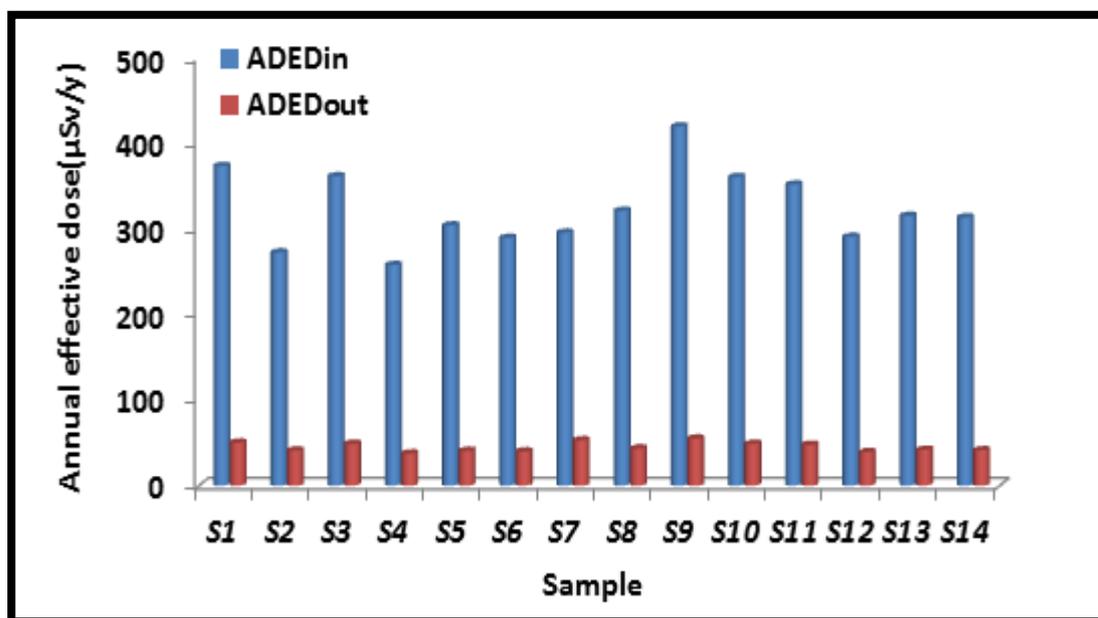


Figure 4. Annual effective dose equivalent in samples sediment of Tigris river.

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 <sub>out</sub>	H <sub>in</sub>	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± 0.040	0.265± 0.019	1181.41± 29.19	153.138± 5.2
Limit[22]	1		1.16 ×10 <sup>-3</sup>	0.29 ×10 <sup>-3</sup>

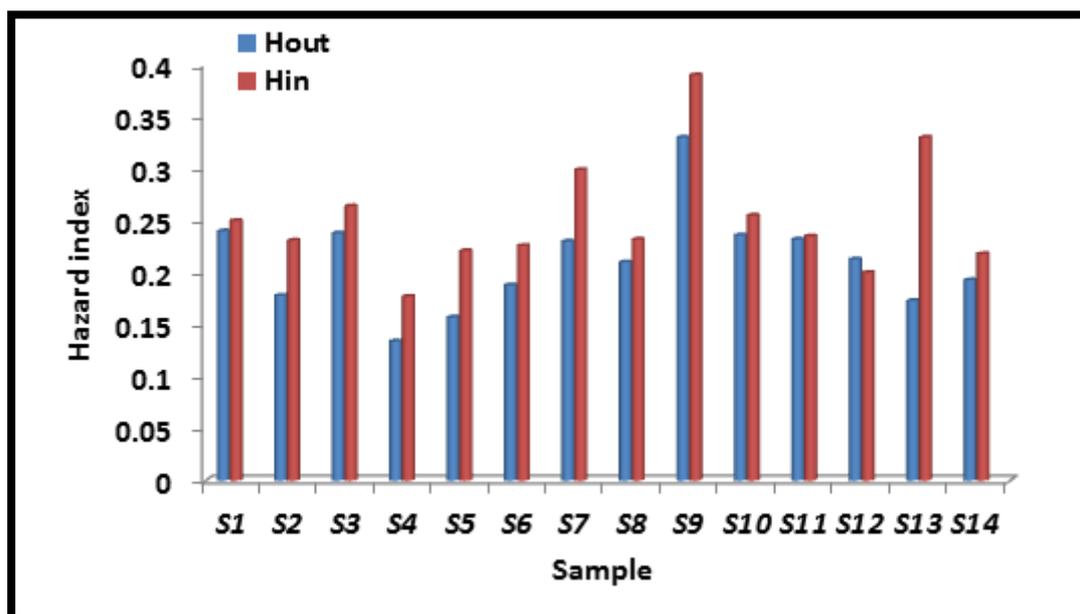


Figure 5. Hazard index in Sediment of Tigris river.

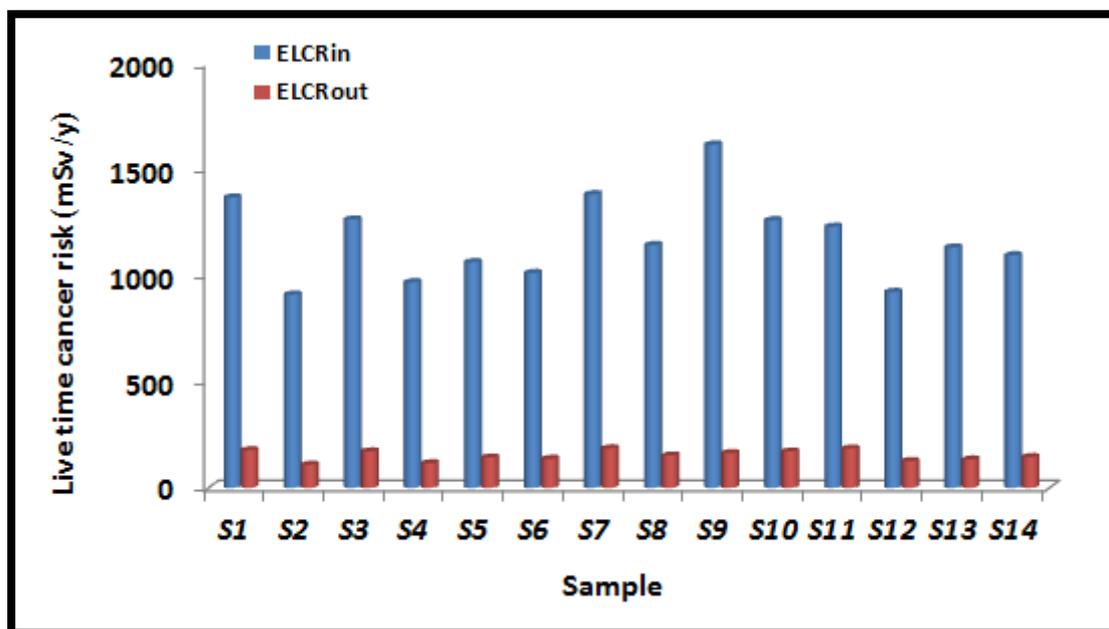


Figure 6. Extra Life Time cancer risk in Sediment of Tigris river.

## 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 concenspecific activity concentration of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  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.

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