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Natural Radionuclides and Hazards in Water and Sediment Samples of Tigris River in Al- Amara city - Maysan - Iraq.

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Abstract
The concentrations of the radionuclides namely ^{238}U, ^{232}Th, and ^{40}K are measured for water and Sediment Tigris River in AL-Amara city- Missan government- Iraq. Using HPGe detector, based on high-resolution gamma spectrometry system and an energy resolution of (≤1.8 keV) for the 133 MeV gamma transition of ^{60}Co. The concentrations of ^{238}U, ^{232}Th and ^{40}K were B.D.L. in all water samples except one sample (Hai Al Hassan Alaskary) which has concentrations of ^{40}K(6.818±1.999 Bq/kg). Radium equivalent activity, absorbed gamma dose rate, annual effective dose rate $(AED)_{in}$ and annual effective doses$(AED)_{out}$, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index were(0) for all water samples except one sample (Hai Al Hassan Alaskary) which have (0.524 Bq /kg), (0.284 nGy /h), (0.0013 mSv/y), (0.00034 mSv/y), (0.0014), (0.0014), (0.004) , respectively .The ^{238U}, ^{232}Th, and ^{40}K concentrations in the Sediment Tigris River varies from (15.379±1.999 - 24.737±1.269)Bq/kg, (9.930±1.033-16.303±1.437) Bq/kg, and (210.628±12.238-415.215±20.750) Bq/kg with over all mean value of (18.220±1.404Bq/kg), (13.792±1.302 Bq/kg), and (317.343±16.997Bq/kg), respectively. The radium equivalent rate (Ra_{eq}) calculated from concentration of ^{238}U, ^{232}Th, and ^{40}K, ranges between(45.798 - 72.368) Bq /kg with mean value (63.879 Bq/kg). The absorbed dose Rate(D_{γ}) for the sediment samples in the study area ranges from (21.886 -35.054) nGy/h with an average value of (29.981nGy/h). The annual effective dose rate $(AED)_{in}$ range(0.107 -0.171 mSv/y) with an average value of (0.146 mSv/y). The annual effective dose rate $(AED)_{out}$ range(0.026 -0.042 mSv/y) with an average value of (0.036 mSv/y). The internal hazard index (H_{in}) range (0.165-0.252) with an average value of (0.217). The external hazard index (H_{ex}) range (0.123-0.195) with an average value of (0.167). The gamma Index (I) range (0.342-0.553) with an average value of (0.470). The values of the specific activity of (^{238}U, ^{232}Th, and ^{40}K), radium equivalent activity, absorbed dose Rate, indoor and outdoor annual effective dose rates, internal and external hazard indicies, gamma index, all were found to be lower than their corresponding allowed limits.
Keywords: AL-Amara city, sediment, Natural radio activity, Radium-equivalent activities, annual effective dose rate (AED), Gamma Index.

1. Introduction
Naturally occurring radioactive materials (NORM) consist of uranium, thorium, potassium and any of their decay products such as radium and radon. Concentrations of these natural radioactive elements are very low in the earth's crust and atmosphere. These elements can be brought to the surface by human activities. Although the radioactive elements in the earth's crust are the reasons of presence of radioactivity in water resources, high concentration of radioactive materials in water resources might be accidentally or intentionally [1]. Sediments have been widely used as environmental indicator and their ability to trace contamination sources and monitor contaminants is widely recognized. Sediments originate from soils and rocks. Radionuclides are present in rocks in varying amounts, and they are easily mobilized into the environment. Radioactivity in sediments results from the parent rock which they are derived. The distribution of naturally occurring radionuclides depend on the distribution of rocks from which they originate and the processes which result to their removal from the soil and migrate them[2].Therefore, the naturally environmental radioactivity mainly depends on geological and geophysical conditions [3].The concentration of natural radionuclides in the rock varies considerably depending on the rock formation and lithological character [4]. The public can be affected by the environment where is adjacent to the released point of the radioactive materials [5]. If radioactive materials are released into the environment, radionuclides may be moved into the body by inhalation and ingestion, which causes internal exposure [6]. The objective of this study is to determine the activity concentrations of natural radionuclides (^{238}U, ^{232}Th, and ^{40}K) in water and sediment samples collected from Tigris River in AL-Amara city and estimate the radiological hazard associated with the water and sediments by using high purity germanium (HPGe) detector.

2- Experimental Method
2-1 sampling and pre-treatment
A total 6 of surface water samples were collected with using GPS from Tigris River in AL-Amara city(as shown in figure 1)at atypical volume 5 letter and put into a bottle size 5 letters. The water samples (5 L) were brought to

the laboratory, heated for enough time to convert (5L) to (1L). (1L) filtered by using polycarbonate filters of 5µm mesh, and 10 mL of concentrated HCl was added to the filtered water to achieve a pH < 2[7,8]. A total of 6 sediment samples were collected with using GPS from Tigris River in AL-Amara city(as shown in figure 1). After transporting the samples to the laboratory, all sediment samples were dried at 80C° for two hours, pulverized, homogenized, and sieved through 75µm mesh [9]. The filtered water and meshed sediment samples were transferred to Marinelli beakers (500 ml capacity) for radio nuclide analysis. The soil samples were weighed, placed into labeled plastic cases, and stored for 30 days to allow secular equilibrium of ^{226}Ra with its decay products in the uranium series. The activity of ^{214}Bi and ^{214}Pb in equilibrium was assumed to represent the ^{238}U activity [9]. Gamma-spectrometry analysis of samples was made with HpGe (Canberra- P-type) with 62 mm crystal diameter and 60 mm crystal length. The detector has a photo peak relative efficiency of ≥40 %. To reduce the gamma-ray background, the detector is shielded in 10 cm thick lead, And enveloping Detector from the inside with a thin layer of cadmium thick (1.6 mm) and thin layer of copper thickness (0.4mm) to attenuation X-ray resulting of interaction gamma rays with a lead material. Energy calibration efficiency of the detector were carried out using Multi- Gamma source that contained (Am-241, Cd-109, Ce-139, Co-57, Co-60, Cs-137, Sn-113, Sr-85, Y-88) emitting gamma rays in the energy range between 59.54 MeV and 1836.08 MeV. Sample measuring times ranged within 3600 sec.

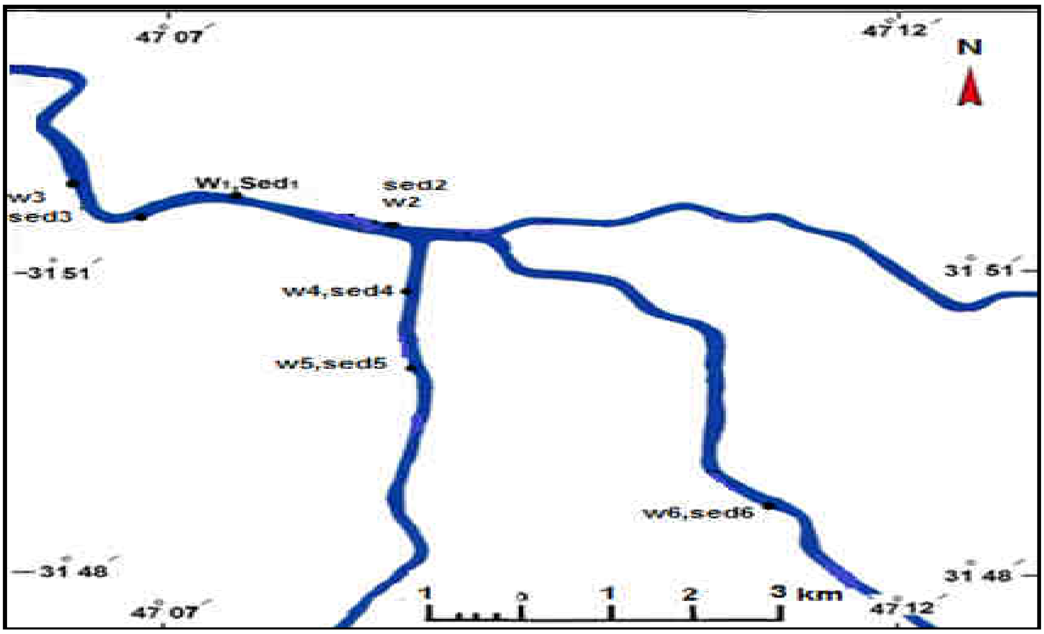

Figure 1: Map of the studied area with sampling location.

2-2 Gamma Radiation Parameters

1-Radium Equivalent Activity (Ra_{eq})

To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclides ^{238}U, ^{232}Th and ^{40}K and is given by the expression [10]:

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad \ldots\ldots(1)$$

Where A_{Ra}, A_{Th} and A_K are the specific activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg) respectively.

2- Absorbed Gamma Dose Rate(D)

Outdoor air gamma absorbed dose rate (D) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface which can be computed from specific activities A_{Ra}, A_{Th} and A_K of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg) respectively using the following relation [10]:

$$D\left(\frac{\text{nGy}}{\text{h}}\right) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

3-Annual Effective Dose Rate (AED)
The estimated annual effective dose equivalent received by a member was calculated by using a conversion factor of (0.7 Sv/Gy), which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20 % and 80 % for indoors [11]:

$$AEDE_{\,out}(mSv.y^{-1}) = D(nGy.h^{-1}) \times 8760h \times 0.7Sv.Gy^{-1} \times 0.2 \times 10^{-6} \quad .....(3)$$

$$\mathrm{AEDE}_{\,\mathrm{in}}(\mathrm{mSv.y^{-1}}) = \mathrm{D(nGy.h^{-1})} \times 8760\mathrm{h} \times 0.7\mathrm{Sv.Gy^{-1}} \times 0.8 \times 10^{-6} \quad ......(4)$$

4-External (Hex) and Internal (Hin) Hazard Indices

The external hazard index is obtained from (Raeq) expression through the supposition that its allowed maximum value (equal to unity) correspond to the upper limit of Raeq (370 Bq/kg) . Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad ....(5)$$

The external hazard index (H_{ex}) can then be defined as given below [10]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad . ...(6)$$

This index value must be less than unity in order to keep the radiation hazard to be insignificant.

5-The Gamma Index (Iγ)

The gamma index (I) for soil samples was calculated by using the following equation [12]***:***

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad ....(7)$$

3- Results and Discussion
From Table (1)it can be noticed that the specific activity of (^{238}U) and(^{232}Th) were B.D.L. in all studied regions in AL-Amara city. The specific activity of (^{40}k) was B.D.L. in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was (6.818±1.999 Bq/L).

Table (1): Specific activity of (^{238}U, ^{232}Th, and ^{40}K), for water Tigris River in AL-Amara city.

Number of samples	Location	Y axis	X axis	U-238 (Bq/L)	Th-232 (Bq/L)	K-40 (Bq/L)
W_1	Hai Al Moualimin Al Jadied	31.86001	47.13066	B.D.L	B.D.L	B.D.L
W_2	Hai Al Rabea	31.85589	47.14497	B.D.L	B.D.L	B.D.L
W_3	Hai Al Karar	31.86030	47.12324	B.D.L	B.D.L	B.D.L
W_4	Hai Al Shabana	31.84569	47.14829	B.D.L	B.D.L	B.D.L
W_5	Hai Al Askan	31.83740	47.14740	B.D.L	B.D.L	B.D.L
W_6	Hai Al Hassan Al Askary	31.83032	47.18350	B.D.L	B.D.L	6.818±1.999

B.D.L: Below Detection Limit
D.L for (^{40}k)= 2.503 Bq/L
D.L for (^{238}U)= 0.347 Bq/L

From Table (2) it can be noticed that the radium equivalent activity (Raeq) was (0 Bq/kg) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was (0.524 Bq/kg). The absorbed gamma dose rate (Dɣ) was (0 nGy/h) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was (0.284 nGy/h). The value of indoor annual effective dose rate (AED) in was (0 mSv/y) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was(0.0013 mSv/y). The value of outdoor annual effective dose rate (AED)out was (0 mSv/y) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was(0.00034 mSv/y). The value of internal hazard index (H_{in}) was (0) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was(0.0014). The value of external hazard index (H_{ex}) was (0) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was(0.0014). The value of the gamma Index (Iɣ) was(0) in all studied regions in AL-Amara city expect (Hai Al Hassan Alaskary) was(0.004).

Table (2): Radium equivalent activity (Raeq), absorbed gamma dose rate (Dɣ), annual effective dose rate (AED) $_{in}$ and annual effective doses(AED) $_{out}$, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index (Iɣ) for water Tigris River in AL-Amara city.

No. of samples	Location	Ra_{eq} (Bq/Kg)	$D_ɣ$ (nGy/h)	AEDE (m Sv/y)		Index Hazard		Iɣ
				IN	OUT	H_{in}	H_{ex}	
W_1	Hai Al Moualimin Al Jadied	0	0	0	0	0	0	0
W_2	Hai Al Rabea	0	0	0	0	0	0	0
W_3	Hai Al Karar	0	0	0	0	0	0	0
W_4	Hai Al Shabana	0	0	0	0	0	0	0
W_5	Hai Al Askan	0	0	0	0	0	0	0
W_6	Hai Al Hassan Al Askary	0.524	0.284	0.00139	0.00034	0.0014	0.0014	0.004
	Global limit[13]	370	84	0.5	0.07	1	1	1

From Table (3) it can be noticed that the highest value of specific activity of (^{238}U) was found in(Hai Al Alaskan) region which was equal to (24.737±1.269Bq/kg), while the lowest value of specific activity of (^{238}U) was found in (Al Hassan Al Askary) region which was equal to (15.379±1.999 Bq/kg), with an average value of (18.220±1.404 Bq/kg) . The highest value of specific activity of (^{232}Th) was found in (Hai Al Rabea) region which was equal to (16.303±1.437Bq/kg), while the lowest value of specific activity of (^{232}Th) was found in (Al Hassan Al Askary) region which was equal to (9.930±1.033Bq/kg), with an average value of (13.792±1.302 Bq/kg). The highest value of specific activity of (^{40}K) was found in (Hai Al Rabea) region which was equal to (415.215±20.750 Bq/kg), while the lowest specific activity of (^{40}K) was found in (Al Hassan Al Askary)regions which was equal to (210.628±12.238 Bq/kg), with an average value of (317.343±16.997 Bq/kg).

Table (3): Specific activity of (^{238}U, ^{232}Th, and ^{40}K), for Sediment Tigris River in AL-Amara city.

No. of samples	Location	Y axis	X axis	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
Sed_1	Hai Al Moualimin Al Jadied	31.86001	47.13066	19.675±2.287	13.772±1.281	354.140±18.454
Sed_2	Hai Al Rabea	31.85589	47.14497	17.082±1.002	16.303±1.437	415.215±20.750
Sed_3	Hai Al Karar	31.86030	47.12324	15.926±0.938	14.579±1.349	360.644±18.897
Sed_4	Hai Al Shabana	31.84569	47.14829	16.525±0.933	12.137±1.278	289.829±15.823
Sed_5	Hai Al Askan	31.83740	47.14740	24.737±1.269	16.031±1.434	273.607±15.821
Sed_6	Hai Al Hassan Al Askary	31.83032	47.18350	15.379±1.999	9.930±1.033	210.628±12.238
	average			18.220±1.404	13.792±1.302	317.343±16.997
	Global limit [14]			25	25	370

From Table (4) it can be noticed that the highest value of radium equivalent activity (Raeq) was found in (Hai Al Rabea) region which was equal to (72.368 Bq/kg) , while the lowest value of radium equivalent activity was found in (Hai Al Hassan Al Askary) region which was equal to (45.798 Bq/kg), with an average value of (63.879Bq/kg). The highest value of absorbed gamma dose rate(Dɣ) was found in (Hai Al Rabea) region which was equal to (35.054 nGy/h) , while the lowest value of absorbed gamma dose rate was found in (Hai Al Hassan Al Askary) region which was equal to (21.886 nGy/h), with an average value of (29.981nGy/h). The highest value of indoor annual effective dose rate (AED)in was found in (Hai Al Rabea) region which was equal to (0.171mSv/y) , while the lowest value of indoor annual effective dose rate was found in (Hai Al Hassan Al Askary) region which was equal to (0.107 mSv/y), with an average value of (0.146 mSv/y) . The highest value of outdoor annual effective dose rate (AED)out was found in (Hai Al Rabea) region which was equal to (0.042 mSv/y) ,while the lowest value of outdoor annual effective dose rate was found in (Hai Al Hassan Al Askary) region which was equal to (0.026 mSv/y), with an average value of (0.036 mSv/y) . The highest value of internal hazard index (Hin) was found in (Hai Al Askan) region which was equal to (0.252) , while the lowest value of internal hazard index was found in (Hai Al Hassan Al Askary) region which was equal to (0.165), with an average value of (0.217). The highest value of external hazard index (Hex) was found in (Hai Al Rabea) region which was equal to (0.195) ,while the lowest value of external hazard index was found in (Hai Al Hassan Al Askary) region which was equal to (0.123), with an average value of (0.167). The highest value of the gamma Index (Iɣ) was found in (Hai Al Rabea) region which was equal to (0.553) , while the lowest value of activity concentration index was found in (Hai Al Hassan Al Askary) region which was equal to (0.342), with an average value of (0.470).

Table (4): Radium equivalent activity (Raeq) , absorbed gamma dose rate (Dɣ), annual effective dose rate (AED) $_{in}$ and annual effective doses(AED) $_{out}$, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index (Iɣ) for Sediment Tigris River in AL-Amara city.

No. of samples	Location	Ra_{eq} (Bq/Kg)	$D_ɣ$ (nGy/h)	AEDE (mSv/y)		Index Hazard		Iɣ
				IN	OUT	H_{in}	H_{ex}	
Sed_1	Hai Al Moualimin Al Jadied	66.638	32.176	0.157	0.039	0.233	0.179	0.504
Sed_2	Hai Al Rabea	72.368	35.054	0.171	0.042	0.241	0.195	0.553
Sed_3	Hai Al Karar	64.544	31.202	0.153	0.038	0.217	0.174	0.492
Sed_4	Hai Al Shabana	56.198	27.051	0.132	0.033	0.196	0.151	0.424
Sed_5	Hai Al Askan	68.731	32.521	0.159	0.039	0.252	0.185	0.507
Sed_6	Hai Al Hassan Al Askary	45.798	21.886	0.107	0.026	0.165	0.123	0.342
	average	63.879	29.981	0.146	0.036	0.217	0.167	0.470
	Global limit [13]	370	84	0.5	0.07	1	1	1

4- Conclusions

The present results have shown that the specific activity of (^{238}U), (^{232}Th) and (^{40}k) in water samples were B.D.L. in all studied regions expect (Hai Al Hassan Al Askary) which has concentrations of ^{40} k (6.818±1.999 Bq/L). The present results have shown that values of Radium equivalent activity, absorbed gamma dose rate, annual effective dose rate (AED) in and annual effective doses(AED) out, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index for the water and sediment samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (370 Bq/kg), (84 nGy/h), (0.5 mSv/y), (0.07mSv/y),(1),(1),(1), respectively[13]. The present results have shown that values of specific activity of (^{238}U), (^{232}Th) and (^{40}K) for the sediment samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (25 Bq/kg), (25 Bq/kg) and (370 Bq/kg), respectively[14]. The present results have shown that values of Radium equivalent activity, absorbed gamma dose rate, annual effective dose rate (AED) $_{in}$ and annual effective doses(AED) $_{out}$, hazard indices(H_{in}) and (H_{ex}) , and the gamma Index for sediment samples in the studied regions in AL-Amara city were lower than the value of the global limit which is equal to (370 Bq/kg), (84 nGy/h), (0.5 mSv/y), (0.07mSv/y),(1),(1),(1), respectively[13]. These levels confirm the absence of any unusual nuclear activities within the region during the last period doubled from those levels.

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