Study the contamination of Radioactivity levels of $^{226}$Ra, $^{232}$Th and $^{40}$K in (water)Iraq and their potential radiological risk to human population

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Abstract
In this study, the level of natural radioactivity in the banks of the Euphrates River was evaluated of four sites for the passage of the Euphrates (Al Kufa , Abu Sukhair, Al Mishkhab and Al Qadisiyah) , as samples were collected along the Euphrates River within the province of Najaf. The radioactivity of naturally formed radioactive materials of Uranium-238 and Thorium-232 series soluble strands in addition to the Potassium -40 radioisotope was determined using the NaI (Tl) sodium iodide reagent system (3"x3"). The values of normal radioactivity were measured in units (Bq.L$^{-1}$). Where was The concentration ranged from 16.44 to 143.88 (Bq.L$^{-1}$) for $^{40}$K , 0.90 to 6.16 (Bq.L$^{-1}$) for $^{238}$U and 1.17 to 5.29 (Bq.L$^{-1}$) for $^{232}$Th. The radium equivalent activity was below the defined limit of 370 (Bq.L$^{-1}$), the calculated exterior hazard indices had been determined to be much less than (one) from the results. Therefore that can be considered as database of these rivers in the future. Also we calculated that the average committed effective dose by ingestion of water for a typical adult was found to be 0.269 mSv.y$^{-1}$ note that the average internal dose of 290 µSv.y$^{-1}$ measured by the Scientific Committee of the United Nations on the Effects of Radiation for food and water consumption. finally we found out Excess lifetime cancer risk is $0.672*10^{-3}$ which is significantly less than the ICRP cancer risk of $2.5 \times 10^{-3}$ which mean that the samples are safe healthy.

Keywords: NaI(TI) , Gamma spectrometry, Euphrates, Water, Iraq.

Introduction
Snow and rain water are additionally early indications of radioactive contamination. In some locations rain water and drinking water can be important pathways of brief
lived radionuclides, e.g. radioiodine, to animals or to humans[1]. Household water and Drinking water are probably essential pathways, via their use in meals processing and preparation, though dilution, time delays and water remedy can minimize the contamination degrees markedly. Water of irrigation functions and/or consumed by livestock can additionally be a supply of radionuclides in foods. Sea water can be an infection supply for seafood (e.g. algae, shellfish, mussels, fish). Water from lakes, streams and ponds need to additionally be viewed as a supply of contamination[2,3]. Naturally going on radioactive substances (NORM) consist of Uranium, Thorium, Potassium and any of their decay merchandise such as Radium and Radon. Concentrations of these natural radioactive elements are very low in atmosphere and also in the earth’s crust [2]. These elements can be introduced to the surface Through the activities carried out by humans. 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 [3]. The public are affect by the environment where is adjacent to the sources of the different radioactive materials [4]. If radioactive substances are launched into the environment, radionuclides might also be moved into the physique by using inhalation and ingestion, which causes internal exposure[5]. Due to the relevance of this topic and its effects on human health, I have carried out a number of studies in this regard as, analyzed samples of water from the river Nile and in the regions Abu Tig, Assiut governorate, Egypt, for concentrations of natural radioactivity and their contribution to the absorbed dose. [6]. Study Groundwater from Assalamia-Alhomira and Juban areas (southeast of Sana'a) and hot spring water from Dempt area (south Sana'a) in Yemen were analyzed for $^{226}$Ra, $^{232}$Th and $^{40}$K activity concentrations. Each sample was measured with a gamma-ray spectrometer NaI(Tl) [7], analyzed samples of water from the Province of Malaysian for concentrations of natural radioactivity and their contribution to the absorbed dose from water samples using gamma spectroscopy technique [8]. analyzed samples of water from the Western Province of Arabia for concentrations of natural radioactivity and their contribution to the absorbed dose from water samples using gamma spectroscopy method[9]. Also, They estimated that the radiological health burden on all human populations was negligible and had no health consequences and had no effect on the background ionization. In a research study, mean concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K were found to be 11.3 ± 2.3, 5.2 ± 0.4 and 140.9 ± 30.6 mBq.L$^{-1}$, respectively using gamma spectroscopy techniques. To measure natural radioactivity of different brands of Widely available bottled drinking water in the federal capital of Pakistan, Islamabad and Rawalpindi[10]. The UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated that exposure to natural radionuclides contributes approximately 70 per cent of the population radiation dose. The global average human exposure to natural sources is 2.4 mSv.y$^{-1}$ and the ratio of water and food is around 0.3mSv.y$^{-1}$[11]. The aim of this study is to obtain a representative estimate of the concentration levels of natural radionuclides in water bodies that could be used as drinking water from the Euphrates at some of our sites studied, Najaf-Iraq. As well as estimating the possible doses of radiation for people ingesting this water. The results obtained will contribute to base data on radionuclide concentrations in this area.

**Description of the study area**

Euphrates is one of the main rivers in Southwest Asia, originating in Turkey. Flowing through Turkey to the south, and then through Syria to the southeast. After it flows
within Syria’s borders, the river flows into northwestern Iraq at Al Qaim in the Governorate of Al Anbar and continues to flow and serve seven Governorates (Babylon, Karbala, Al Najaf, Al Qadesia, Al Muthanna, Al Nasiriya and Al Basra) and the western part of Baghdad. The Euphrates then converge with the Tigris River in southern Iraq in the Shat Al Arab Waterway into the Arab Gulf. Euphrates River has two branches in Al-Najaf Al-Ashraf Governorate: Al Abbasia River, the eastern branch, and Al Kufa River, the western branch. We started collecting samples from Al Kufa River (at location 32° 08’ 77.4˝ N, 44° 21’ 55.8˝ E), which penetrate the towns: Al Kufa, Abu Sukhair, Al Mishkhab and when it enters to Al Qadisiyah divide into Al Atshan River and Al Qadesia River. We completed the samples from Al Qadesia branch to finalize the sampling at the site (31° 38’ 34.07˝ N, 44° 30’ 24.99˝ E) at the southern borders of the governorate of Al-Najaf Al-Ashra as shown in Figure (1). Therefore the total distance studied for the river is about 65 km. We have researched this river, because it plays an important role in local irrigation. This river watering agricultural operations which extend extensively to both sides of the river and the surrounding area. Interesting NORMs from the Euphrates River are directly related to the scale of local agricultural activities that may result in pollution and raise the amount of background radioactivity in the surrounding areas.

![Figure (1): Map for Euphrates river inside Al-Najaf Governorate](image_url)

**Experimental**

Twenty five samples from the bottom river were collected to estimate the levels of natural radioactivity in the Euphrates river. Such samples were taken from regular positions along the River Euphrates within the limits of the Al Najaf Al Ashraf administrative governorate. We divided the river into 25 positions, with a distance about 1200 meters between the two positions during August 2011. The sampling positions were determined using global positioning system (GPS). After removal of...
impurities, each water sample was packaged in labeled polyethylene bags and sent to the laboratory of radiation detection and measurement in the physics department, College of science, University of Kufa. Table (1) Listed descriptions of existing water sampling locations from the Euphrates River. For water samples 1 L was transferred to a Marinelli beaker for each sample. The Marinelli-beaker was then sealed and kept for at least five weeks. The daughter of radon achieves equilibrium with $^{226}\text{Ra}$ during this time. Then, the samples were ready for gamma spectroscopy analysis [9].

**Table (1): Name of the sampling locations with their latitude and longitude.**

| Sample code | Location      | Latitude (°N) | Longitude (°E) |
|-------------|---------------|---------------|----------------|
| W1          | Al-Kufa       | 32°08’77.4”   | 44°21’55.8”    |
| W2          |               | 32°08’09.2”   | 44°21’47.8”    |
| W3          |               | 32°07’13.8”   | 44°21’26.8”    |
| W4          |               | 32°06’48.9”   | 44°21’40.0”    |
| W5          |               | 32°06’07.6”   | 44°21’94.3”    |
| W6          |               | 31°57’66.0”   | 44°27’91.1”    |
| W7          | Abu Sukhair   | 31°57’03.4”   | 44°28’12.0”    |
| W8          |               | 31°56’47.6”   | 44°28’48.9”    |
| W9          |               | 31°56’07.5”   | 44°29’07.6”    |
| W10         |               | 31°55’51.0”   | 44°29’32.2”    |
| W11         | Al-Mishkhab   | 31°54’27.8”   | 44°29’65.5”    |
| W12         |               | 31°35’79.2”   | 44°30’09.1”    |
| W13         |               | 31°35’19.9”   | 44°30’19.7”    |
| W14         |               | 31°52’56.5”   | 44°30’11.4”    |
| W15         |               | 31°51’96.9”   | 44°29’75.0”    |
| W16         |               | 31°48’69.7”   | 44°29’59.0”    |
| W17         |               | 31°48’07.8”   | 44°29’86.8”    |
| W18         |               | 31°47’13.4”   | 44°30’50.2”    |
| W19         |               | 31°48’63.8”   | 44°30’57.1”    |
| W20         |               | 31°46’06.6”   | 44°30’83.6”    |
| W21         |               | 31°45’52.7”   | 44°31’09.8”    |
| W22         |               | 31°44’93.9”   | 44°30’75.5”    |
| W23         |               | 31°44’38.9”   | 44°30’39.1”    |
| W24         |               | 31°43’81.7”   | 44°30’07.0”    |
| W25         |               | 31°43’29.1”   | 44°29’64.5”    |

**Gamma-ray detection system**

The samples activity of $^{226}\text{Ra}$, $^{232}\text{Th}$, and $^{40}\text{K}$ was measured using a scintillation-based radiation detector including sodium iodide activated by thallium NaI(Tl). The detector with a resolution of 1.89 keV at 1.33MeV of $^{60}\text{Co}$. The detector was maintained in a vertical position and shielded by lead to reduce the effect of the radiation background. The spectrum analysis was carried out using the computer program MAESTRO multichannel analysis.

**Calculations**
The specific activity in Bq.L⁻¹ units was calculated for each individual isotope by using the equation (1) [12].

\[ \mathcal{A}_n = \frac{(C_n - C_b)}{\varepsilon \gamma I \gamma m_s} \]  

where \( \mathcal{A}_n \) is the specific activity of each radionuclide in Bq.L⁻¹, \( C_n \) the count rate in cps for a sample, \( C_b \) the count rate in cps for background, \( \varepsilon \gamma \) and \( I \gamma \) are detection efficiency and emission probability of \( \gamma \)-ray, \( \tau \) is the counting time and \( m_s \) is the mass of the sample in kg. There is no uniform distribution of \(^{40} \text{K}, ^{226} \text{Ra} \) and \(^{232} \text{Th} \) nuclei in rocks and soil, so a specific factor was used to compare their combined radiological effects. This factor is called the Radium equivalent activity (\( \mathcal{R}_{e q} \)). As proposed by the Organization of Economic Cooperation and Development, the allowed Radium equivalent activity values should be less than 370 (Bq.L⁻¹) for safe use. Equation (2) was used to calculate the radium equivalent activity (\( \mathcal{R}_{e q} \))[12].

\[ \mathcal{R}_{e q} = \mathcal{A}_{Ra} + 1.43 \mathcal{A}_{Th} + 0.077 \mathcal{A}_K \]  

where \( \mathcal{A}_{Ra} \), \( \mathcal{A}_{Th} \) and \( \mathcal{A}_K \) are the specific activity of \(^{226} \text{Ra}, ^{232} \text{Th} \) and \(^{40} \text{K} \) respectively.

The external (\( \mathcal{H}_{ex} \)) and internal (\( \mathcal{H}_{in} \)) hazard indices were calculated with Equations (3) and (4) [13].

\[ \mathcal{H}_{ex} = \frac{\mathcal{A}_{Ra}}{370} + \frac{\mathcal{A}_{Th}}{259} + \frac{\mathcal{A}_K}{4810} \]  

\[ \mathcal{H}_{in} = \frac{\mathcal{A}_{Ra}}{185} + \frac{\mathcal{A}_{Th}}{259} + \frac{\mathcal{A}_K}{4810} \]  

If the calculated indices values are greater than unity, radioactivity can harm the population.

Equation (5) was used to calculate the outdoor dose (\( \mathcal{D}_{out} \)) [14], and the average value is 51 nGy.h⁻¹ as recommended by the UNSCEAR (2000) report.

\[ \mathcal{D}_{out} = 0.462 \mathcal{A}_{Ra} + 0.604 \mathcal{A}_{Th} + 0.0417 \mathcal{A}_K \]  

While the indoor absorbed dose rate for samples was calculated by using equation (6) [14].

\[ \mathcal{D}_{in} = 0.92 \mathcal{A}_{Ra} + 1.1 \mathcal{A}_{Th} + 0.08 \mathcal{A}_K \]  

The annual effective dose equivalent from outdoor terrestrial gamma radiation is[14]:

\[ \mathcal{D}_{eff} = \text{Outdoor dose(nGy. h}^{-1}) \times 0.7 (\text{Sv. Gy}^{-1}) \times 8760 (\text{h.y}^{-1}) \times 0.2 \]  

For indoor exposure, using an occupancy factor of 0.8, the annual effective dose equivalent is[14]:

\[ \mathcal{D}_{eff} = \text{indoor dose (nGy. h}^{-1}) \times 0.7 (\text{Sv. Gy}^{-1}) \times 8760 (\text{h.y}^{-1}) \times 0.8 \]  

the average annual committed effective dose, \( \mathcal{E}_{ave} \), for ingestion of NORMS in the water were calculated using the expression below:

\[ \mathcal{E}_{ave} = \mathcal{C}_r \times DCF_i \times A_i \]  

Where \( DCF_i \) is the dose convection factor for ingestion, for each radionuclide (i.e., \( 4.5 \times 10^{-5} \) mSv.Bq⁻¹, \( 2.3 \times 10^{-4} \) mSv.Bq⁻¹ and \( 6.2 \times 10^{-6} \) mSv.Bq⁻¹ for \(^{238} \text{U}, ^{232} \text{Th} \) and
\[ ^{40}\text{K} \] respectively for an adult (UNSCEAR 2000). \( \text{Cr} \) is the consumption rate Intake of NORMS in water and \( A_{i} \) is the concentration of activity in the water sample. The Average annual committed effective dose (AACED) measurements resulting from the ingestion of natural radioactive materials (NORMs) into water.

**Results and discussion**

After More than 400 people in Iraq were asked in different regions. According to the answer, we took the average daily consumption per person, which was 1.5 liters daily, the results were as follows:

**Radioactivity characterization of the of the Euphrates waters.**

The activity concentrations of \( ^{232}\text{Th} \) and \( ^{40}\text{K} \), Radium equivalent activity, External and Internal indexes, outdoor and indoor Absorbed Dose, total gamma dose, outdoor and Indoor annual effective dose (Total annual effective dose equivalent) for the collected water samples are shown in table (2)(3)(4) and also shown in figures (2),(3),(4) respectively. It's clear from these tables and figures that the maximum values on site W25 in Al-Qadesia (31°43' 29.1''N - 44°29' 64.5''E), the proportions rise in the sample 25 because this region is famous of cultivation of rice, so chemical fertilizers are added to this region at every agricultural season. While the maximum activity concentration of \( ^{238}\text{U} \) is found in site W3 in Al-Kufa (32°07' 13.8''N - 44°21' 26.8''E) which may be because the nature of the land of Kufa, which is called gravel (mixing of sand and clay) that is, the geology of the land there. on the other hand \( ^{232}\text{Th} \), \( ^{40}\text{K} \) and Radium equivalent activity, External and Internal indexes, outdoor and indoor Absorbed Dose, total gamma dose, outdoor and Indoor annual effective dose (Total annual effective dose equivalent) for the collected water samples they reached the peak in site W6 (31°57' 66.0''N - 44°28' 12.0''E) too, where the percentages are low for the sample W6, because this region is an orchards and they use organic fertilizers only and rarely use chemical fertilizers. It must be noted that the concentration of radionuclides in water is determined by the aquifer's chemical and physical properties and by the Uranium content of the geological formation involved.

**Table (2) Activity concentration and radium equivalent activity (Bq L\(^{-1}\)) \( ^{40}\text{K}, ^{238}\text{U} \) and \( ^{232}\text{Th} \) of water of present study area**

| Sample code | position         | \( ^{40}\text{K} \) (Bq L\(^{-1}\)) | \( ^{238}\text{U} \) (Bq L\(^{-1}\)) | \( ^{232}\text{Th} \) (Bq L\(^{-1}\)) | Ra\(_{eq}\) (Bq L\(^{-1}\)) |
|------------|------------------|------------------------------------|------------------------------------|------------------------------------|------------------|
| W\(_1\)    | Al-Kufa          | 56.81±2.05                         | 1.52±0.66                          | 3.69±0.30                          | 11.17±1.25       |
| W\(_2\)    | Al-Kufa          | 66.47±2.05                         | 4.22±0.66                          | 2.28±0.36                          | 12.59±1.33       |
| W\(_3\)    | Al-Kufa          | 18.16±1.06                         | 6.16±0.52                          | 2.09±0.26                          | 10.54±0.98       |
| W\(_4\)    | Al-Kufa          | 22.60±1.44                         | 2.04±1.09                          | 1.41±0.30                          | 5.80±1.63        |
| W\(_5\)    | Al-Kufa          | 68.75±2.44                         | 1.61±0.62                          | 4.54±0.30                          | 13.39±1.23       |
| W\(_6\)    | Abu Sukhair      | 16.44±5.11                         | 1.75±0.71                          | 1.17±0.49                          | 4.69±1.80        |
| W\(_7\)    | Abu Sukhair      | 49.59±1.94                         | 0.90±0.62                          | 1.37±0.43                          | 6.68±1.38        |
| W\(_8\)    | Abu Sukhair      | 85.41±2.61                         | 1.18±0.47                          | 1.90±0.41                          | 10.48±1.27       |
| W\(_9\)    | Abu Sukhair      | 65.19±2.33                         | 4.31±0.57                          | 3.82±0.30                          | 14.80±1.18       |
| W\(_10\)   | Abu Sukhair      | 46.87±1.94                         | 2.37±0.19                          | 3.28±0.30                          | 10.66±1.67       |
| W\(_11\)   | Al-Mishkhhab     | 73.63±2.44                         | 5.12±0.47                          | 2.35±0.49                          | 14.15±1.36       |
Figure (2): Distribution of specific activity and radium equivalent activity.

table (3): External and internal radiation hazard, Indoor and Outdoor Absorbed Dose and Activity concentration index (Iγ) of water samples

| Sample code | H_{ext} | H_{int} | Outdoor Absorbed Dose (nGy h^{-1}) | Indoor Absorbed Dose (nGy h^{-1}) | I_γ (Bq L^{-1}) |
|-------------|---------|---------|-----------------------------------|-----------------------------------|----------------|
| W_{12}      | 0.030   | 0.034   | 5.53                              | 7.19                              | 0.085          |
| W_{13}      | 0.034   | 0.045   | 6.17                              | 8.02                              | 0.095          |
| W_{14}      | 0.028   | 0.045   | 4.79                              | 6.23                              | 0.074          |
| W_{15}      | 0.016   | 0.021   | 2.78                              | 3.61                              | 0.043          |
| W_{16}      | 0.036   | 0.041   | 6.65                              | 8.64                              | 0.102          |
| W_{17}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{18}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{19}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{20}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{21}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{22}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{23}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{24}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |
| W_{25}      | **0.013** | **0.017** | **2.23**                          | **2.90**                          | **0.034**      |

Average: 65.34±2.61, 3.16±0.69, 3.00±0.38, 12.48±1.43
Minimum value: 16.44±5.11, 0.90±0.62, 1.17±0.49, 4.69±1.80
Maximum value: 143.88±3.55, 6.16±0.52, 5.29±0.40, 23.33±1.50

Worldwide [15, 16]: 400, 35, 30, 370
Table (4): Outdoor, indoor annual effective dose equivalent, sum total and AACED of water samples.

| Sample | D_{outdoor} | D_{indoor} |
|--------|-------------|------------|
| W_7    | 0.018       | 3.43       |
| W_8    | 0.028       | 5.44       |
| W_9    | 0.040       | 7.17       |
| W_{10} | 0.029       | 5.20       |
| W_{11} | 0.038       | 6.91       |
| W_{12} | 0.038       | 7.04       |
| W_{13} | 0.037       | 6.83       |
| W_{14} | 0.043       | 7.86       |
| W_{15} | 0.030       | 5.54       |
| W_{16} | 0.040       | 7.21       |
| W_{17} | 0.038       | 6.79       |
| W_{18} | 0.037       | 6.73       |
| W_{19} | 0.042       | 7.78       |
| W_{20} | 0.030       | 5.66       |
| W_{21} | 0.051       | 9.24       |
| W_{22} | 0.027       | 4.97       |
| W_{23} | 0.030       | 5.41       |
| W_{24} | 0.025       | 4.55       |
| W_{25} | 0.063       | 11.69      |

Average: 0.034
Minimum value: 0.013
Maximum value: 0.063

Figure (3): Distribution of Outdoor, Indoor Absorbed Dose (nGy. h^{-1}) of water sample.
| Sample code | Outdoor annual effective dose equivalent (mSv year\(^{-1}\)) | Indoor annual effective dose equivalent (mSv year\(^{-1}\)) | Total annual effective dose equivalent (mSv year\(^{-1}\)) | AACD (mSv.y\(^{-1}\)) |
|-------------|-------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------|
| W\(_1\)     | 0.0068                                                       | 0.0353                                                      | 0.0421                                                      | 0.218                    |
| W\(_2\)     | 0.0076                                                       | 0.0393                                                      | 0.0469                                                      | 0.290                    |
| W\(_3\)     | 0.0059                                                       | 0.0306                                                      | 0.0365                                                      | 0.369                    |
| W\(_4\)     | 0.0034                                                       | 0.0177                                                      | 0.0211                                                      | 0.151                    |
| W\(_5\)     | 0.0082                                                       | 0.0424                                                      | 0.0506                                                      | 0.256                    |
| W\(_6\)     | 0.0027                                                       | 0.0142                                                      | 0.0169                                                      | 0.128                    |
| W\(_7\)     | 0.0042                                                       | 0.0219                                                      | 0261                                                        | 0.099                    |
| W\(_8\)     | 0.0067                                                       | 0.0347                                                      | 0.0413                                                      | 0.137                    |
| W\(_9\)     | 0.0088                                                       | 0.0458                                                      | 0.0546                                                      | 0.354                    |
| W\(_10\)    | 0.0064                                                       | 0.0331                                                      | 0.0395                                                      | 0.241                    |
| W\(_11\)    | 0.0085                                                       | 0.0441                                                      | 0.0525                                                      | 0.336                    |
| W\(_12\)    | 0.0086                                                       | 0.0449                                                      | 0.0536                                                      | 0.269                    |
| W\(_13\)    | 0.0084                                                       | 0.0436                                                      | 0.0519                                                      | 0.284                    |
| W\(_14\)    | 0.0096                                                       | 0.0501                                                      | 0.0598                                                      | 0.377                    |
| W\(_15\)    | 0.0068                                                       | 0.0353                                                      | 0.0421                                                      | 0.230                    |
| W\(_16\)    | 0.0088                                                       | 0.0460                                                      | 0.0549                                                      | 0.328                    |
| W\(_17\)    | 0.0083                                                       | 0.0433                                                      | 0.0516                                                      | 0.310                    |
| W\(_18\)    | 0.0083                                                       | 0.0429                                                      | 0.0512                                                      | 0.291                    |
| W\(_19\)    | 0.0095                                                       | 0.0496                                                      | 0.0592                                                      | 0.305                    |
| W\(_20\)    | 0.0069                                                       | 0.0361                                                      | 0.0430                                                      | 0.187                    |
| W\(_21\)    | 0.0113                                                       | 0.0589                                                      | 0.0702                                                      | 0.442                    |
| W\(_22\)    | 0.0061                                                       | 0.0317                                                      | 0.0378                                                      | 0.198                    |
| W\(_23\)    | 0.0066                                                       | 0.0345                                                      | 0.0411                                                      | 0.242                    |
| W\(_24\)    | 0.0056                                                       | 0.0290                                                      | 0.0346                                                      | 0.239                    |
| W\(_25\)    | 0.0143                                                       | 0.0746                                                      | 0.0889                                                      | 0.436                    |
| Average     | 0.0392                                                       | 0.0075                                                      | 0.0467                                                      | 0.269                    |
| Minimum value | 0.0027                                                      | 0.0142                                                      | 0.0169                                                      | 0.099                    |
| Maximum value | 0.0143                                                      | 0.0746                                                      | 0.0889                                                      | 0.442                    |
Excess lifetime cancer risk

The risk of cancer due to radiation effects which is called excess lifetime cancer risk (ELCR) can be calculated from the following equation [17].

\[
\text{Cancer risk} = (\text{AACD})_{\text{Sv} \cdot \text{y}^{-1}} \times F (\text{Sv}^{-1}) \quad \cdots (10)
\]

Where, \((E_{\text{ave}})\) the average annual committed effective dose of normal life expectancy (50 years) for adults and risk factor, respectively. The value of risk factor (F) for stochastic effects in the population is 0.05 per Sievert as recommended by ICRP [18]. The average annual committed effective dose for the measured in water in this study, 0.2691 mSv.y\(^{-1}\), that used to estimate the risk of cancer for an adult person using the equation (10) which gives a risk factor of 0.672\(\times\)10\(^{-3}\) Sv. The estimated values are significantly less than the ICRP cancer risk of 2.5 \(\times\) 10\(^{-3}\) based on annual dose limit of 1 mSv for general public, which mean the average of all samples is safe healthy.

Conclusion

Our estimate of concentration of water radioactivity on areas from Iraq's Euphrates River (Al Kufa, Abu Sukhair, Al Mishkhab and Al Qadisiyah) is performed using gamma-ray spectrometry, surface waters play an significant role in radio-nuclide movement and redistribution in the Earth's crust. The maximum activity concentration of 232Th, 40K and Radium equivalent activity, external and internal indexes, outdoor and indoor absorbed dose, total gamma dose, outdoor and Indoor annual effective dose were found in Al-Qadesia (31°43’29.1˝°N - 44°29’64.5˝°E). The maximum activity concentration of 226Ra is found in Al-Kufa (32°07’13.8˝°N - 44°21’26.8˝°E). The research findings include An annual effective doses assessment to estimate an adult person's cancer risk, where the estimated effective annual dosages for all
radionuclides from The intake of drinking water per annum is much less than Recommended reference level. The predicted values for the general population are substantially lower than the ICRP cancer risk of $(2.5 \times 10^{-3})$, therefore recommend that the water be reasonable for human consumption. Therefore, we can consider our results as a basic database for the waters of the Euphrates in these areas.

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