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Relationship of Concentrations of Radioactive Elements of the Kufa River to Soil Geology

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Abstract: *To ascertain and assess the radiation dangers in the river's water, the natural radioactivity levels in water samples along the Kufa River—one of the world's major rivers—in Al Najaf City were examined. Using a NaI(Tl) scintillation detector and a gamma-ray spectrometer, the specific activity of the radionuclides (238U, 232Th, and 40K) in twenty distinct water samples from the Kufa River within AL Najaf city was determined. The average specific activity values for 238U, 232Th, and 40K were (0.883, 2.250, and 43.339) Bq/l, according to the results. The average annual effective doses for adults were found to be 0.170855, 0.357452, and 2.250 mSv/y, respectively. These values are significantly higher than the annual dose limits that are permitted globally (0.26, 0.2, and 0.1 mSv/y for adults, children, and infants, respectively), and they have negative health effects.*

Keywords: *particular activity, radioactive materials, gamma-ray detector, and river water Dosage effective annually.*

I. Introduction

Since the beginning of time, radiation has always been a natural component of our surroundings and is present in every area of our existence. Because of this, life has developed in environments with high quantities of ionizing radiation. Radiation originates from all sources, including our own bodies as well as the earth and space. It is present in the food, water, and air we breathe as well as in the building supplies we use to construct our homes[1].

Roughly 84% of human exposure comes from natural sources, such as radon gas, cosmic rays, and gamma rays. The remaining sixteen percent originates from radiation sources that are man-made. One constant and unavoidable aspect of life on Earth is the exposure of humans to ionizing radiation from natural sources; for the majority of people, this exposure is greater than that from all man-made sources combined [2]. All nuclear radiation sources need to be watched as public awareness of the risks associated with nuclear radiation grows[3].

An essential factor to take into account in ecological investigations is water quality. The earth's crust contains trace levels of radioactive isotopes like potassium, uranium, thorium, and radium, which is the main cause of radioactivity in surface water. The radioactive decay of 238U and 232Th results in multiple series of daughter radioisotopes with distinct physical properties, including decay modes, half-lives, and radiation types and energy released[4]. Natural radioactive material concentrations in the environment have lately increased due to a variety of human activities, including the testing of nuclear weapons, the construction of nuclear power plants, and the production and use of radioactive sources. Through a variety of routes, radioactive materials may enter surface waters as a result of any of the procedures or exercises. Rainwater that overflows its surface and carries radionuclides from mining waste, urban areas, soil weathering, and agricultural areas can contaminate rivers [5]. Furthermore, naturally occurring radioactive materials (NORM soil containing radioactive components are formed by geological processes that lead to another sort of water contamination. Rain and flooding are two ways that NORM can reach rivers[6]. The amount of radioactive materials present in the river's water may change if treated wastewater is released into it.

Generally speaking, providing the scientific basis for forecasting the impacts of different radionuclides on humans and their surroundings is one of the most important aspects of radiological research. To ascertain the radiation exposure and calculate the corresponding human radiation dose, measurements of radiation and radioactivity are necessary. Then, epidemiological research that aims to connect radiation exposure to consequences on human health can be connected to this data. To understand the effects of radioisotopes—natural or man-made released into waterways on aquatic ecosystems, radiological studies in water are crucial [7]. There was a study to measure the concentrations of radionuclides in the river branches of the main river, the Euphrates, in Kufa, and the levels were within the internationally permissible limits, that is, safe for health [8].

One of the papers that dealt with the study of radiation in the field of food[9].

The main objective of the study was to know the levels of radiation in the water of the Kufa River, as it is the basis of the life of the governorate and is considered the main drinking resource that supplies the systems that purify drinking water.

II. Materials and methods

Study area

Kūfah was an important hub for Arab education and culture in the eighth and ninth centuries, located in the medieval city of Iraq. ʕUmar I, the second caliph, established it as a garrison town in 638 CE. The city was located around 7 miles (11 km) northeast of Al-Najaf on the Hindiyyah branch of the Euphrates River. The majority of its residents were from South Arabia and Iran, and it occasionally shared the role of governor of Iraq with its sister city, Basra. The Muslims of Kūfah were the first to back ʿAlī, the prophet Muhammad's son-in-law, in his claims against ʕUthmān ibn ʿAffān, the caliph, in 655. Afterwards, ƆAlī's capital was Kūfah (656–661). Kūfah remained a continual source of turmoil throughout the Umayyad era. It acknowledged ʿAbd Allāh ibn al-Zubayr as caliph in 683 during the civil war that followed the death of caliph Yazīd I; thereafter, in 685, it fiercely rejected the Shīʕite philosophy imposed on it by al-Mukhtār ibn Abī ʕUbayd al-Thaqafī [10]
After being taken over by the ʿAbbasids in 749, the city continued to function as the capital of administration for a while, up until AL Najaf was established. Kūfah fell steadily after the Qarmatians sacked it in 924–925, 927, and 937. By the time the geographer Ibn Baṭṭ\ṭah visited it in the 14th century, it was all but abandoned. Figure 1 and Table 1 illustrate how Kūfah, along with Basra, was a focus for the study of Arabic grammar, philology, literary criticism, and belles letters during its height in the second and third centuries of the Muslim era.

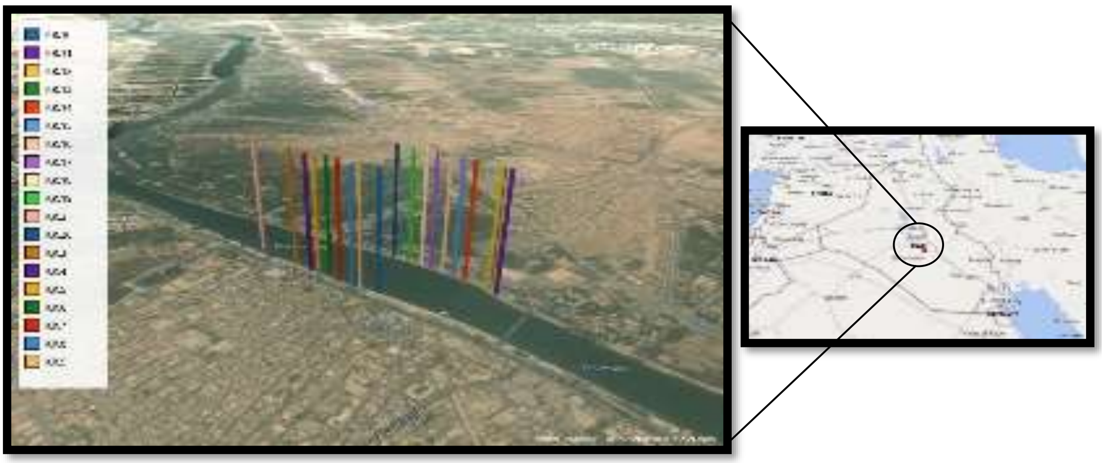

Figure 1. Kufa River study site [10].

Table 1. The locations where water samples from the Kufa River in Iraq were taken.

Sample code	Location coordinates	
	Latitude "N"	Longitude "E"
KR.1	**32.04271**	**44.4016**
KR.2	**32.04304**	**44.40139**
KR.3	**32.04235**	**44.40247**
KR.4	**32.04201**	**44.40292**
KR.5	**32.04211**	**44.4031**
KR.6	**32.04188**	**44.40344**
KR.7	**32.04173**	**44.40372**
KR.8	**32.04142**	**44.40408**
KR.9	**32.0414**	**44.40426**
KR.10	**32.0412**	**44.40472**
KR.11	**32.04139**	**44.40752**
KR.12	**32.04146**	**44.40732**
KR.13	**32.04153**	**44.40736**
KR.14	**32.04187**	**44.4068**
KR.15	**32.04205**	**44.40654**
KR.16	**32.04221**	**44.40626**
KR.17	**32.04237**	**44.40596**
KR.18	**32.042499**	**44.40572**
KR.19	**32.04263**	**44.40541**
KR.20	**32.04285**	**44.40499**

Gathering and preparing samples

Twenty water samples were taken from various locations along the river. January 2022 saw the collection of all the samples. Water samples were collected immediately from the Kufa River's edge using five-liter plastic bottles. In order to reduce the volume of water from (5 to 1) trash, the water samples were heated with an electric heater to 100o C for six hours. The purpose of boiling water is to remove surplus water and raise the radionuclide concentration. Following that, before gamma ray measurement, one litre of each sample, KR, was sealed in Marinelli beakers and kept for 30 days to guarantee radioactive equilibrium between 226Ra and 232Th and their decay products[11]. KR for each sample was measured for 18000 seconds using a NaI(Tl) detector in gamma-ray spectrometry.

Method of experimentation for γ -spectroscopy

Based on high efficiency (60%) KR was used to read the specific activity spectrum data in the current work using a gamma spectrometry system with a sodium iodide NaI(Tl) detector (3"×3") coupled to PCMCA (4096 channel) (model Canberra, USA), voltage (750V). GINE-2000 was the computer program used to examine the detector KR. In order to protect it from background radiation, it was kept vertically and encircled by a lead shield.

Using a standard source of 1.0 L Marinelli beaker of mixed radionuclides with energies (59.53, 88.34, 661.7, 1173.24, and 1332.5) keV for 214Am, 109Cd, 137Cs, and 60Co, respectively, the energy and efficiency calibration of the gamma spectrometer was completed. The radioactivity of the man-made and natural radionuclides in water samples was measured using a counting time of 18,000 seconds[12]. Utilizing the 214Bi activity concentrations at energy (609.31) keV as a proxy for the 238U activity concentration and the 228Ac activity concentration at energy (911.0) keV as a proxy for the 232Th activity concentration. Direct measurements at energy (1460.8) keV and (661) keV were made to determine the activity concentration of 40K and 137Cs, respectively.

Radioactivity Measurements

Activity concentrations in each sample's particular activity concentration in the spectrum , as determined by the following equation [13]:

$$A = \frac{N}{P(E\gamma) \times Eff \times Tc \times V}$$

where: N is the net area under the peak; Vis is the water sample volume (litres); Aff is the detectors' efficiency at energy Eγ; $P(\mathbf{D}\gamma)$ is the intensity at energy Eγ; and Tc is the measurement time that KR.as equal to (7200 s).

Annual Effective Dose Estimation

To estimate the contribution of these radionuclides to public exposure from natural radioactivity, the dosage resulting from the consumption of Kufa river water was computed using the following equation [14,15]:

$DR_w(mSv/y) = A_w \times IR_w \times ID_F$

where: w. denotes the yearly water intake (l/y), k. denotes the activity (Bq/l), d. denotes the annual effective dose (mSv/y), and d. denotes the effective dose conversion factor (mSv/Bq). The doses were determined by utilizing the following conversion factors: 226Ra, 232Th, and 40K; and (2.8 × 10-4, 2.3 × 10-4, and 6.2 × 10-6 mSv/Bq) for adults, as reported by the IAEA, ICRP, and WHO [16,17, 18]. The consumption rates for babies, children, and adults were 150, 350, and 500 l/y, respectively.

Findings and conversation

Table 2 displays the distribution of the radionuclides 40 K, 232Th, and 226Ra that were found in the water samples. In KR, the activity concentration of 226Ra had the lowest value, measuring 0.000 Bq/l.8 locations, with KR.19 having the highest value at 5.131Bq/l and an average of 0.883Bq/l. The activity concentration of 232Th had the lowest value in KR, at 0.094 Bq/kg.12 locations, with 7.376 Bq/l in KR being the highest figure.6. locations with a 2.250 Bq/l average. With an average of 43.339Bq/l, the activity concentration of 40K recorded the maximum value of 193.061Bq/l in KR.11 location and the lowest value of 3.424Bq/l in KR.7 site. The average specific activity of 40K, 232Th, and 226Ra in units (Bq/l) in water samples from different parts of the Kufa River is displayed in Figure 2.

Table 2.Activity concentration of ^{226}Ra, ^{232} Th, ^{40}K in (Bq/l) unit in the water samples of Kufa river

Sample code	^{226}Ra	^{232} Th	^{40}K
KR.1	0.710	1.444	28.321
KR.2	0.016	2.480	18.510
KR.3	0.868	1.538	19.991
KR.4	1.263	1.883	7.682
KR.5	0.039	1.224	6.479
KR.6	0.032	7.376	106.341
KR.7	0.316	3.798	3.424
KR.8	0.000	0.816	21.194
KR.9	1.894	0.251	69.876
KR.10	1.342	4.206	38.131
KR.11	0.395	6.183	193.061
KR.12	0.237	0.094	6.479

KR.13	0.079	2.919	23.138
KR.14	0.710	3.296	81.908
KR.15	0.008	0.220	11.939
KR.16	0.039	0.188	20.084
KR.17	0.055	1.193	18.047
KR.18	0.063	0.691	4.905
KR.19	5.131	1.381	70.246
KR.20	1.105	0.847	7.219
MAX	5.131	7.376	193.061
MIN	0.000	0.094	3.424
AVE.	0.883	2.250	43.339

The worldwide average concentrations of the radionuclides ^{238}U, ^{232}Th, and ^{40}K reported by UNSCEAR (2000) [19] are 12.0 Bq/l, 1.0 Bq/l and 12.0 Bq/l, respectively. Our results show that the average activity concentrations of ^{238}U ,^{232}Th and ^{40}K in our samples are much higher than the worldwide average concentrations also the result draw as comparative in figure 2.

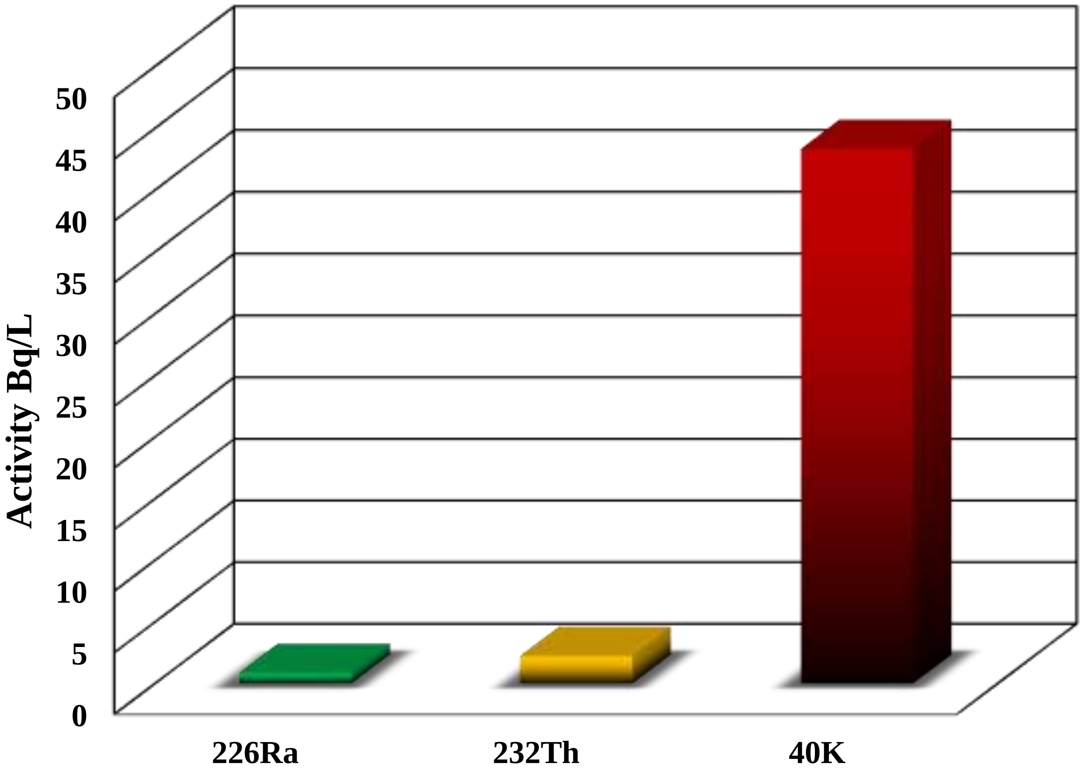

Figure 2. The mean specific activities of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg were measured in water samples from different study areas.

Table 3 displays the estimated yearly effective dose for adults based only on the consumption of 226Ra, 232Th, and 40K. According to the table, for the adult age group under study, the dosages varied from 0.992377 mSv/y to 0.00 mSv/y with an average value of 0.170855 mSv/y, from 1.171864 mSv/y to 0.01496 mSv/y with an average value of 0.357452 mSv/y, and from 0.82682582 mSv/y to 0.014665655 mSv/y with an average value of

0.185608812 mSv/y.

The total annual effective dose (DRw) (in mSv/y) resulting from ingesting the combined amount of all three radionuclides is depicted in Figure 3. The average dosages from ingestion (0.666299) were greater than those seen globally. It is evident from the data, which are also shown in Figures 4,5, that the doses taken by adult.

The effective annual doses for adults suggested by the IAEA, WHO, and UNSCEAR are 0.26, 0.2, and 0.1 mSv/y. The doses obtained in this investigation are significantly greater than these reference levels [20,21, 22]. This leads one to the conclusion that either consumption should be reduced or the concentration of radionuclides should be raised since the waters under investigation are not suitable for human consumption over the long term.

Table 3. Total yearly effective dose (DRw) (mSv/y) for adult intake of 226Ra, 232Th, and 40K determined from Kufa River water samples.

Sample code	^{226}Ra, (mSv/y)	^{232}Th, (mSv/y)	^{40}K, (mSv/y)	Total ingestion (mSv/y)
KR.1	0.137406	0.229386	0.121288927	0.488081
KR.2	0.003053	0.393946	0.079273808	0.476273
KR.3	0.167941	0.244346	0.085615713	0.497903
KR.4	0.244277	0.299199	0.03289863	0.576375
KR.5	0.007634	0.19448	0.027745833	0.229859
KR.6	0.006107	1.171864	0.455428028	1.633399
KR.7	0.061069	0.603385	0.014665655	0.67912
KR.8	0	0.129653	0.09076851	0.220422
KR.9	0.366416	0.039893	0.299258626	0.705568
KR.10	0.259545	0.668212	0.163304045	1.091061
KR.11	0.076337	0.982371	0.82682582	1.885533
KR.12	0.045802	0.01496	0.027745833	0.088508
KR.13	0.015267	0.463759	0.09909226	0.578118
KR.14	0.137406	0.523599	0.350786602	1.011791
KR.15	0.001527	0.034907	0.051131606	0.087565
KR.16	0.007634	0.02992	0.086012082	0.123566
KR.17	0.010687	0.189493	0.077291963	0.277472
KR.18	0.012214	0.109706	0.021007559	0.142928
KR.19	0.992377	0.219413	0.300844102	1.512634
KR.20	0.213743	0.13464	0.030916785	0.379299
KR.21	0.992377	1.171864	0.82682582	1.885533
KR.22	0	0.01496	0.014665655	0.087565
KR.23	0.170855	0.357452	0.185608812	0.666299
MAX	0.992377	1.171864	0.82682582	1.885533
MIN	0	0.01496	0.014665655	0.087565

AVR.	0.170855	0.357452	0.185608812	0.666299

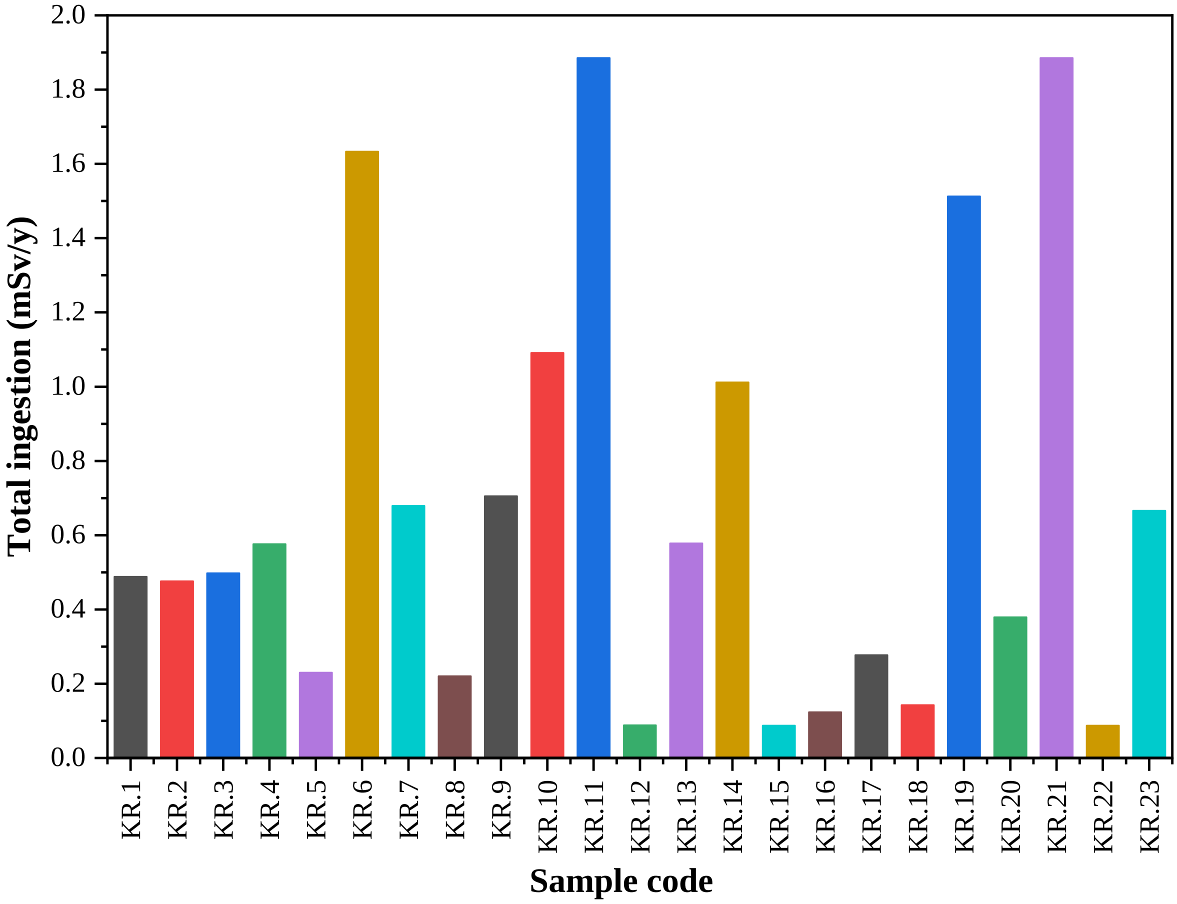

Figure 3. Total yearly effective dose (DRw) mSv/y resulting from adult consumption of Kufa River water inside AL Najaf city, as determined by the examined water samples.

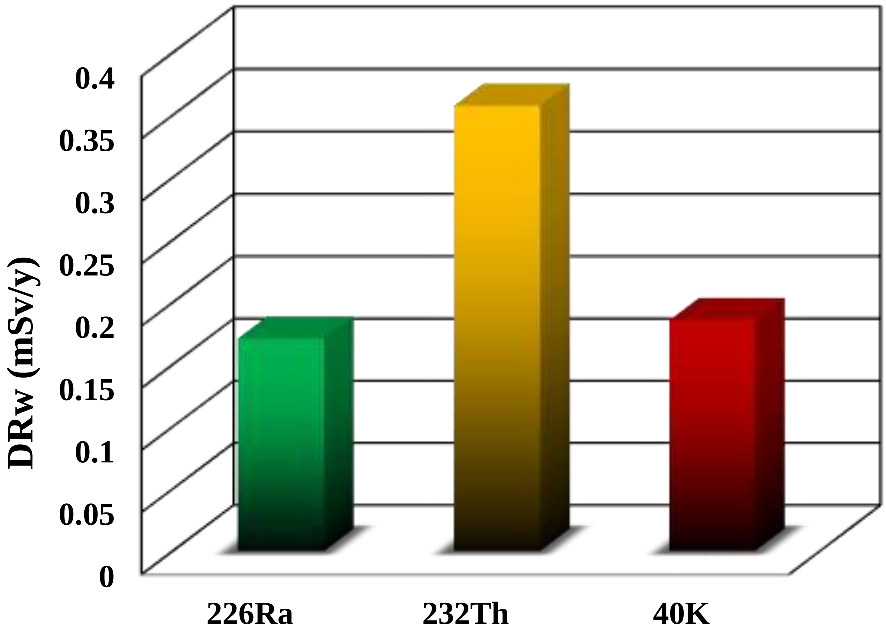

Figure 4. The average of the yearly effective dose (DRw) of 226Ra, 232Th, and 40K for adults ingested in water samples.

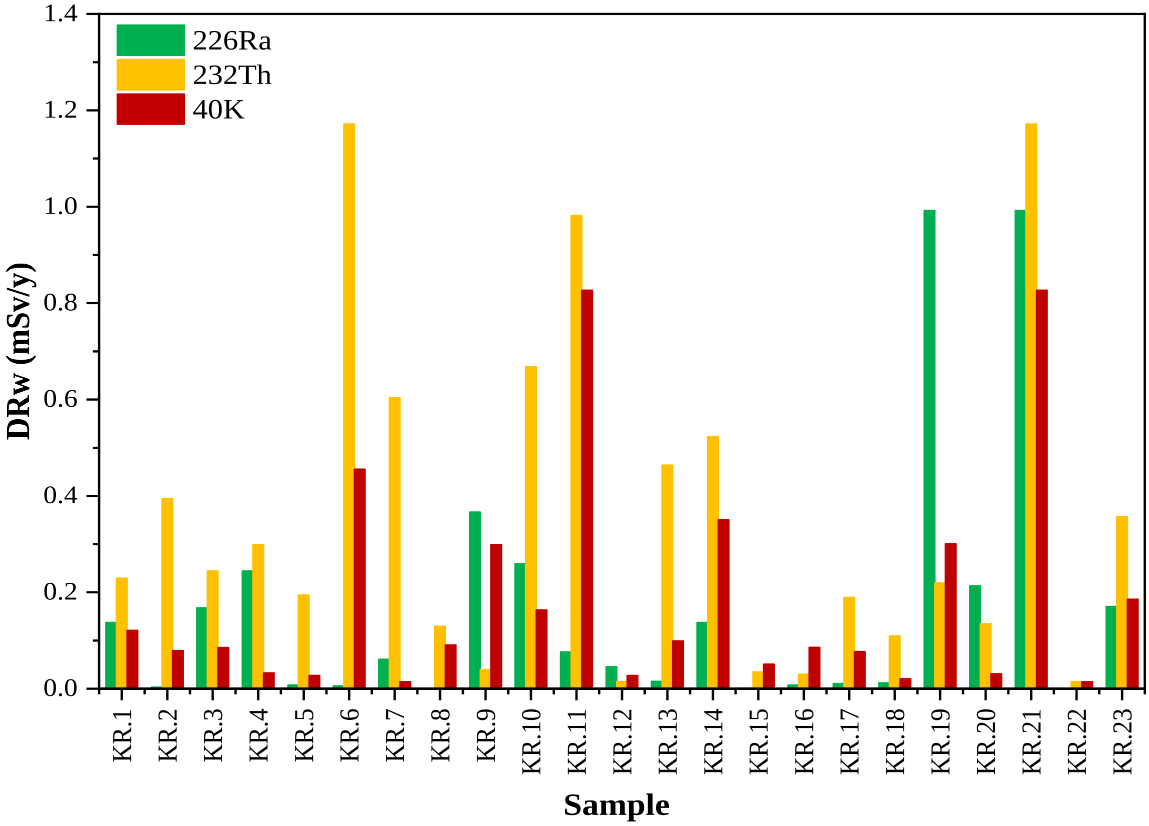

Figure 5. The average of the total annual effective dosage (DRKssR.) (mSv/y) for adults resulting from water consumption from the Kufa River in AL Najaf city.

III. Conclusion

The investigation includes a large area of the Iraqi city of AL Najaf's Kuf River. Using gamma-ray spectroscopy and a NaI(Tl) detector, the collected data were used to provide information about the radioactive concentrations in the water of the Kufa River. The average amounts of 238U, 232Th, and 40K in water samples are significantly greater than the suggested worldwide limits, according to our findings.

Our tests also revealed that the yearly effective dose rate values were significantly greater than the UNSCEAR, wHO, and IAEA recommended limits, which may have negative health implications, particularly for youngsters. This leads to the conclusion that the water under investigation is unfit for human consumption and that significant efforts should be made to enhance the quality of the water in the Kufa River, namely in Al Najaf City.

The information acquired may be helpful for mapping natural radioactivity, and this study might be used as a foundation for further research. It seems that figuring out how much radioactivity is in the water from other areas of Iraq is required. The outcomes might also serve as a starting point for upcoming radioactive pollution observations.

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