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Original Research Paper

Estimation of the Radioactive pollution in west of Basra groundwater by using gamma-ray spectroscopy/ Iraq

[1] Karar Matouq Sadiq
[2] Riyadh Mnade Ramadhan

[1,2]*Department of Physics, College of Science, University of Basra, Basra, Iraq*

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Abstract

Groundwater is one of the most important water resources used for drinking water and irrigation of crops in the study area, so it is necessary to ensure the safety of groundwater from radionuclides and to identify its risks to human health. ***Aim****: To achieve the objective of current study by determining the level of radioactivity of U-238, Th-232, and K-40 in groundwater, gamma-ray spectroscopy and radioactivity level analysis was used.* ***Methods****: Ten samples of groundwater in the Safwan region were tested. The results showed that the concentrations of radionuclides for U-238, Th-232, and K-40 ranged from 0.021–1.855 Bq/L, 0.047–1.736Bq/L, and 4.822–32.439 Bq/L, respectively.* ***The resulted*** *data is seen to be within the limits allowed by UNSCEAR, except for two samples, the reason is due to the geological nature of the aquifer. In addition to that, radiation hazard indicators were calculated, including the activity of radium (Ra_{eq}), which ranges from 0.926–4.481 Bq/L which is less than the recommended 370 Bq/L by UNSCAR. The average dose absorbed in the air ($D_{\gamma} nGy/h$) ranges between 0.485–2.238nGy/h and it was within the permissible limits. The external hazard index (H_{ex}) was between 0.0025–0.01209, the internal hazard index (H_{in}) was between 0.00255–0.01695, and the gamma (I_{γ})index was between 0.00777–0.03453. Also, results show that the radiation hazard indicators were lower than the ones recommended by UNSCEAR.* ***Conclusion:*** *Based on this study's results on the radioactivity level, groundwater is safe to use.*

Keywords: *Radioactivity, Groundwater, Pollution, NaI (TI) detector, Natural Radionuclides*

1.Introduction

Radioactivity is the process of the spontaneous decay of nuclear atoms, leading to the release of energy and atomic particles. This radioactive decay involves the transformation of the original radioactive isotopes into stable isotopes, either directly or by decay chains that include unstable nucleons of smaller sizes. Radioisotopes are types of atoms that do not have enough nuclear binding energy to carry many protons or neutrons without losing their stability. Although there are many naturally occurring isotopes in the environment, more extremely unstable isotopes are also being produced in laboratories.[1]. In this regard, the natural radiation comes from two sources, cosmic radiation, and decay of radionuclides. The original radionuclides are formed naturally in the Earth's crust and include the decay chain of radionuclides and radionuclides produced through cosmic radiation reactions[2]. An estimated 85% of global radiation doses come from natural sources, and this is leading to growing concern about radiation exposure in the environment and its impact on human health and the ecosystem[3]. One of the primary sources of radioactivity is the decay of natural radionuclides (NORM) such as Th-232 and U-238 in the Earth's crust.

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The radioactivity in groundwater may reach a particular threshold. Because of its interaction with rocks and soil, it can be detected. Some species are found in dissolved form as ionic species, and the most prevalent elements in groundwater are U, Po, Ra, and Th[4]. The groundwater and the level of natural pollution are affected by the geographical status and composition of the rocks of the aquifer as well as the human factor, such as agricultural, industrial, and mining activities[5]. K-40 is one of the only isotopes of potassium, which is found in water bodies because of the interaction of water with soil and rocks. Th-232 is considered one of the elements that do not dissolve significantly in water, and the reason is its presence in elements that are difficult to dissolve. Regarding U-238, in lakes, rivers, and groundwater, it generally varies between 0.1 and 10 micrograms[6]. The concentration of these minerals rises together with the growth of industrial activity. These materials are scattered because of industrial processes or human activity. Materials with high amounts of natural radioactivity that can be transferred and reused include industrial deposits, drilling mud, and layers that stick to the tubes[7]. Water is a necessary component of both the environment and life. There must be no pollution in the water. All plant and animal life depends on water, and there are two main natural sources: surface water from freshwater lakes, rivers, and streams, and groundwater from wells and boreholes. The human body is exposed to this kind of radiation through food, drink, or inhalation[8]. The natural processes in the human body can fix radiation-induced damage to DNA at low exposure levels. Elevated exposure, however, inhibits these repair systems and is harmful to human health, increasing the risk of developing various cancers[9]. One of the top three causes of mortality in underdeveloped nations and the second most common cause of death worldwide is cancer. It is a global health concern[10]. Thus, identifying radioactive contaminants and keeping a close eye on the amount of radioactivity in groundwater is crucial to preventing possible radiation exposure among the general public[4]. This research seeks to ascertain the extent of radioactive pollution in groundwater as well as the dangers connected to radionuclide concentrations of Th-232, U-238, and K-40. Samples were gathered in the governorate of western Basra from different places. Evaluating natural radioactivity, its effect on human health, and the extent of radiation exposure are the main objectives of the study.

2. Methodology:

Study area and samples preparation

In the western and southwestern parts of Iraq, the study area includes the city of Safwan and the area around Mount Sanam and is located between latitude and longitude lines 30 and 47. The study site was chosen to be the western section of the city of Basra, which is in the southernmost region of Iraq and along the Kuwaiti border. Groundwater is considered an indispensable resource for agricultural irrigation and drinking water due to its position and the scarcity of surface water. Because groundwater is used more frequently, it is critical to assess the radioactivity level in these areas and identify any negative effects.

Ten samples were taken from several locations in the western city of Basra, including the vicinity of Mount Sanam and the city of Safwan in August 2023. The samples were collected using 1-liter plastic containers from different areas as seen in Fig (1). They were washed with diluted hydrochloric acid before use for them to preserve the water samples. Radionuclide absorption on the container walls is reduced thanks to the acid. The location of each sample was determined using GPS, and Table (1) contains the samples information and the depth of each sample. The samples were transferred to Marinelli containers after being washed with hydrochloric acid and rinsed to prevent the loss of nuclides on the container wall[11]. 0.5 liter of each sample was used and sealed for at least 45 days to achieve radionuclide equilibrium.

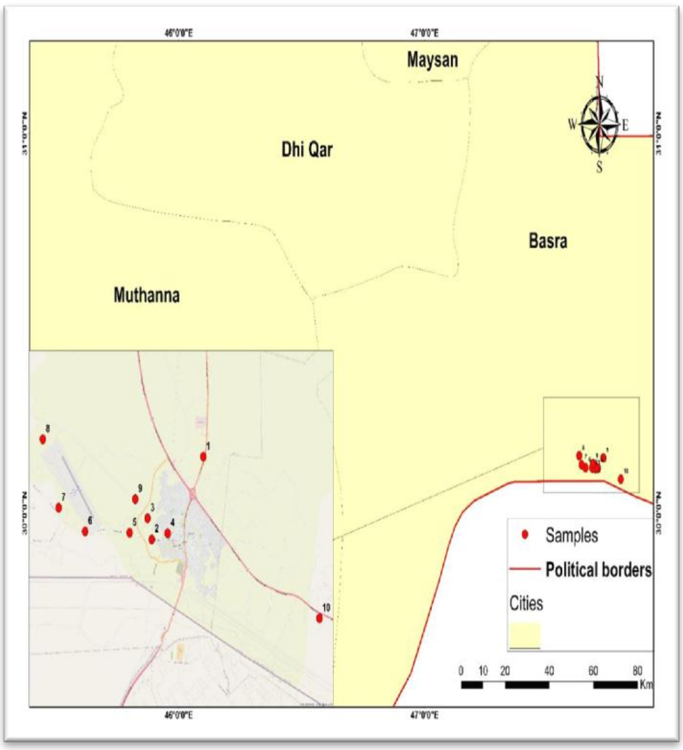

Figure (1): Map of study area

Table (1): contains the latitude and longitude, the code of each sample and the depth of each sample.

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Sample	Geographical location	Depth
HK01	30.144936, 47.727429	18
HK02	30.116506, 47.695858	20
HK03	30.123772, 47.693287	30
HK04	30.118620, 47.705565	25
HK05	30.118781, 47.682280	20
HK06	30.119272, 47.655021	20
HK07	30.127409, 47.638793	20
HK08	30.150944, 47.629107	23
HK09	30.130382, 47.685800	20
HK010	30.089373, 47.798581	24

The level of radionuclides was measured using a sodium iodide crystal detector (NaI) (3*3) doped with thallium, coupled with a multi-channel analyzer containing 4096 channels and software my (MCA) computer. The energy was calibrated through standard sources to ascertain the energies. Two elements were used namely, the Cs-137 with energy (661.32) KeV, and the Co-60 with energy (1173.2 and 1332) KeV, respectively, in the Marinelli container, and the gamma spectrum was compiled for the same time (3600s) to obtain the energy for each source. The efficiency of the detector was calibrated using the two standard sources, Cs-137 with energy (661.32) KeV, and Co-60 with energy (1173.2, 1332.5) KeV, respectively. The calculation of the activity level and presence of U-238 and Th-232 in all samples was derived by the arithmetical average of activities taken from the peaks. of their daughters in the water spectrum. U-238 is derived from Bi-214 (609.32 KeV). Th-232 is derived from Pb-212, Ac-228 with energies of (238.63, 968.97) KeV, respectively. The activity values of K-40 in all samples were determined from the single peak of potassium at 1460.82 KeV.

The concentrations of U-238, Th-232, and K-40 activity were calculated in groundwater samples in Bq/L units using the relation [12].

$$A = \frac{N-B.G}{\varepsilon \times t \times I_\gamma \times V} \qquad (1)$$

A: - The radioactive content of groundwater expressed in Bq/L units.
N: - The net total area under the slope of the radioactive element.
B.G: - A net area without sample presence.
ε: - The efficiency of the detector.
I_γ : - Relative intensity.
t: - Time of creation of the spectrum. (s).
V: - Sample volume (L)

For assessing the potential danger of radioactivity in groundwater, risk indicators were computed.

Represents the concentrations of radioactivity of radionuclides U-238, Th-232, and K-40, which are calculated according to the following relation:

$$Ra_{eq}\left(\frac{Bq}{L}\right) = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

Values that are higher than 370 Bq/L represent a danger to human health[13].
The absorbed dose of air is defined as the amount of energy absorbed by a person. The absorbed gamma dose depends on the radioactivity of the radionuclide and is calculated according to the following relation $D_\gamma\left(\frac{nGy}{h}\right)$ [14]:

$$D_\gamma\left(\frac{nGy}{h}\right) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \qquad (3)$$

Radiation hazard indicators are defined as the external hazard index (H_{ex}) and the internal hazard index (H_{in}), and each value represents the amount of internal and external exposure to radioactive elements. The value should be less than one[15]. equations (4) and (5).

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (4)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

Equation (6) is used in calculating the gamma hazard index associated with the level of radioactive radionuclides in groundwater samples[16].

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \qquad (6)$$

3.Result and Discussions

Natural radio element concentrations in the ten samples collected throughout the research region are displayed in Table (2). The quantities of the K-40 non-decay series and the natural decay chains of U-238 and Th-232 were measured for these samples using a NaI (TI) detector in a laboratory setting. Figure 3 displays a plot of these results, which show a range of 0.021 to 1.855 Bq/L an average value of 0.6945 Bq/L, for U-238, 0.047 to 1.736 Bq/L with an average value of 0.4798 Bq/L, for Th-232, 4.822 to 32.439 Bq/L, average value of 19.49908 Bq/L for K-40 respectively. The concentrations that arise from this activity differ between groundwater samples. The significant changes in the rare earth elements, chemical, and mineral properties of the groundwater that occur in various host rocks may be the cause of these differences in their concentrations [17]. The values for U-238 are highest in HK01 sample and lowest in HK06 sample, it was found that most of the values were within the limits of the general average (1 Bq/L) WHO [18]. Thorium-232 was found to have higher value in HK03 sample lowest in HK09 sample, all values were within the limits

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recommended by the WHO (1 Bq/L). Finally, with regards to radionuclides, K-40 has been shown to have a larger value than other radionuclides in all the sample sites, sample site HK02 had the lowest value of K-40, while site HK09 had the greatest value. This elevated worth Notwithstanding the fact that K-40 dissolves in water, it has no effect on the body. As a result, regardless of its intake, it stays steady at that level [19]. It was found that most of the values were within the limits of the general average (10 Bq/L)[20]. The concentrations of U-238, Th-232, and K-40 vary from sample to sample, as Figure (2) illustrates. Table (3) Comparing the concentration of radioactive elements with those from other studies.

Table (2): Radioactivity Bq/L for radionuclides U-238, Th-232, and K-40

K-40(Bq/L)	Th-232(Bq/L)	U-238(Bq/L)	Sample
7.239	0.215	1.855	**HK01**
4.822	0.232	0.491	**HK02**
25.127	1.736	0.064	**HK03**
12.871	0.261	0.637	**HK04**
13.28	0.596	1.059	**HK05**
10.198	0.084	0.021	**HK06**
31.384	0.137	0.302	**HK07**
29.633	0.195	0.043	**HK08**
32.439	0.047	1.855	**HK09**
29.735	0.472	0.131	**HK010**
32.439	1.736	1.855	**Max**
4.822	0.047	0.021	**Min**
19.4990±10.341	0.4798±0.454	0.6945±0.678	**Average**
10 Bq/L	1 Bq/L	1 Bq/L	**Limits WHO**

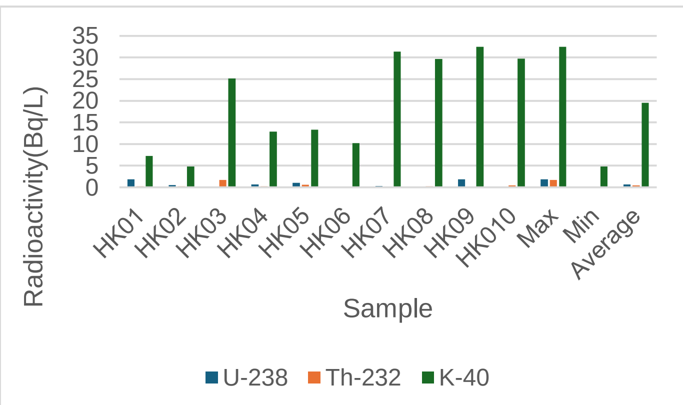

Figure (2): Concentration of radioactivity for U-238, Th-232, and K-40 in groundwater samples

Table (3): Comparing the concentration of radioactive elements with those from other studies.

Country	U-238 (Bq/L)	Th-232(Bq/L)	K-40(Bq/L)	References
Nigeria	1.85- 20.27	14.58- 60.27	123.32- 603.8	[13]
EGYPT	0.97 – 1.60	0.21 – 1.1	9.70 – 23.0	[21]
Namibia	214.28–259.36	0.13– 0.98	0.001 – 0.004	[15]
Nigeria	1.01-8.21	0.97-14.81	4.44-147.33	[17]
Iraq	0.46-2.29	0.44-1.85	7.24-38.49	[11]
Iraq	0.69-1.57	0.88-1.36	25.1-36.89	[22]

Table (4) shows the levels of risk indicators, where the activity values of radium (Ra_{eq} Bq/L) range between (0.926) Bq/L in the sample (HK06) and (4.481) Bq/L in the sample (HK03) at a mean of (2.76025) Bq/L. It is less than the permissible global limit (370 Bq/L), according to the World (WHO)[21], see Figure (3). While the concentration of the absorbed dose of air (D_{γ}) was between (0.485) nGy/h in the sample (HK06) and (2.238) nGy/h in the sample (HK09), at a mean of (1.3583) nGy/h and all values were within the permissible limits, and less than 55 nGy/h, according to the World (WHO)[21], see Figure (4). In addition, the external hazard index (H_{ex}) was calculated to be ranged between (0.0025) in the sample (HK06) and (0.01209) in the sample (HK03) at a mean of (0.007354). Internal hazard index (H_{in}) is between (0.00255) in the sample (HK06) and (0.01695) in the sample (HK09) and at a mean of (0.009218). All values were within the permissible limits and less than one, according to the World (WHO), see Figure (5). The gamma hazard index (I_{γ}) was also calculated a seen to be between (0.00777) in the sample (HK06) and (0.03453) in the sample (HK03) at a mean of (0.02135). The results show that the risk index for cancer is below the permissible limits and less than one (see Figure 6).

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Table (4): the indications of radiation hazard value

Sample	$Ra_{eq}(\frac{Bq}{L})$	$D_{\gamma}(\frac{nGy}{h})$	H_{ex}	H_{in}	I_{γ}
HK01	2.719	1.288	0.00734	0.01236	0.01934
HK02	1.194	0.568	0.00322	0.00455	0.0088
HK03	4.481	2.125	0.01209	0.01227	0.03453
HK04	2.001	0.988	0.0054	0.00712	0.01543
HK05	2.933	1.403	0.00792	0.01078	0.02187
HK06	0.926	0.485	0.0025	0.00255	0.00777
HK07	2.914	1.530	0.00786	0.00868	0.0243
HK08	2.603	1.373	0.00702	0.00714	0.02199
HK09	4.420	2.238	0.01193	0.01695	0.03446
HK010	3.095	1.585	0.00838	0.008712	0.02541
Max	4.481	2.238	0.01209	0.01695	0.03453
Min	0.926	0.485	0.0025	0.00255	0.00777
Average	2.7244	1.3583	0.007354	0.009218	0.02135

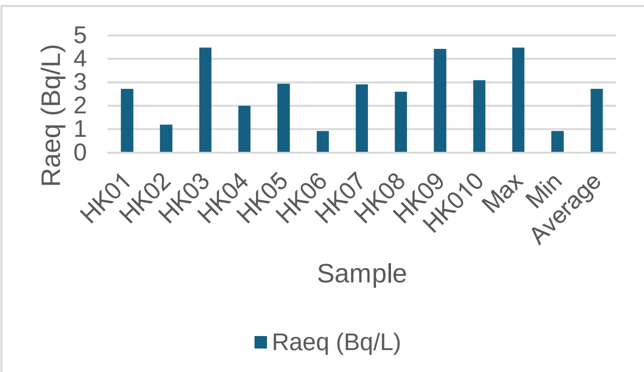

Figure (3): Equivalent values of radium activity in groundwater

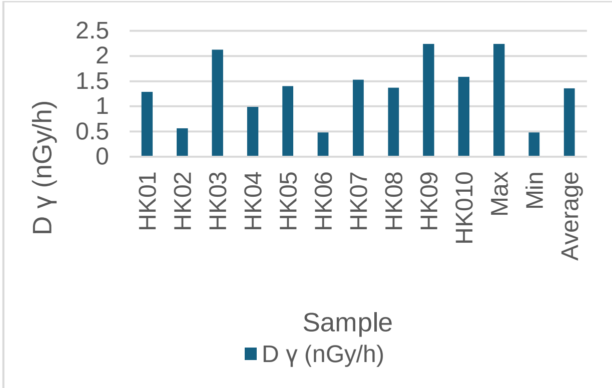

Figure (4): Values of the groundwater's absorbed air dosage

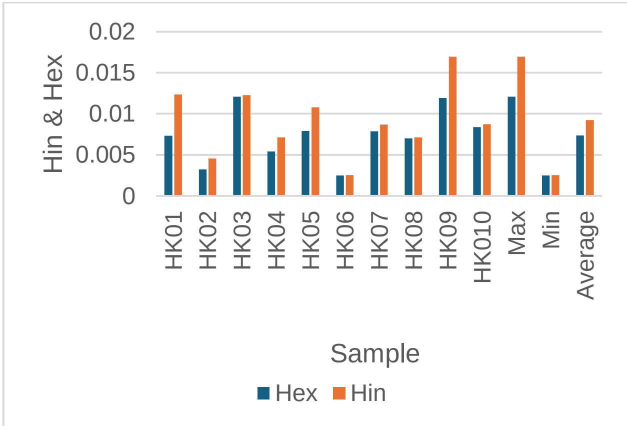

Figure (5) :Values of internal and external groundwater risk indicators

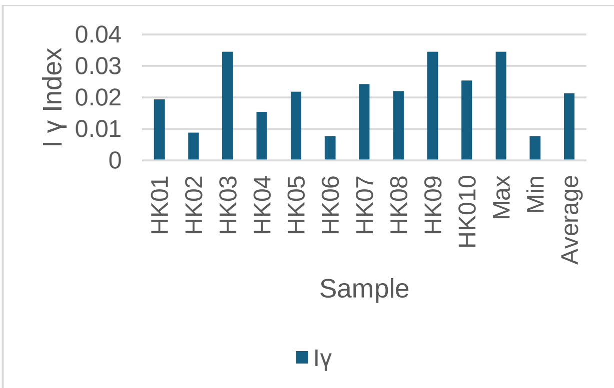

Figure (6): Gamma radiation danger index levels in groundwater

4.Conclusions

The level of radioactivity in groundwater was measured for U-238, Th-232, and K-40 using gamma-ray spectroscopy in 10 samples. The results showed that the

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values of U-238 and Th-232 are within the limits of the general average (1 Bq/L) according to the (WHO), except for the sample (WH08), due to the geology of the area. The mean K-40 values indicate they are within the 10 Bq/L overall mean of the (WHO). In addition, it indicates that the values of radium equivalent activity (Ra_{eq}) are below the recommended limits (370 Bq/L) of the (WHO). Also, the rate of absorbed dose from the air (D_{γ} nGy/h) is within the permissible limits and less than 55 nGy/h. The results of the calculation of the internal hazard index (H_{in}) and the external hazard index (H_{ex}) and the values of the gamma level index (I_{γ}) in those areas for groundwater are less than one and do not pose a danger to the population. We conclude from the obtained values that it is safe for humans.

5.Ethical Approval

The University of Basra, College of Science, Department of Physics, Environmental pollution Lab, has been the site of this work.

6.References

[1] White, W. M. (Ed.). (2018). Encyclopedia of Geochemistry: A Comprehensive Reference Source on the Chemistry of the Earth. Springer International Publishing. https://doi.org/10.1007/978-3-319-39312-4.

[2] Anjum, M. A. M., Siddique, N. S. N., Younis, H. Y. H., Faiz, Y. F. Y., Shafique, M. A. S. M. A., Mahnoor, M. A., Feroze, R. F. R., & Abbasi, N. U. H. A. N. U. H. (2024). Assessment of Heavy Metal Pollution, Radionuclides, and their Health Implications: A Case Study for Murree, Pakistan [Preprint]. In Review. https://doi.org/10.21203/rs.3.rs-3691875/v1.

[3] Kraishan, A., Shayeb, M. A., Belmabrouk, H., Qwasmeh, A. A. H., & Baloch, M. A. (2023). Assessment of natural radioactivity in soil and olive mill pomace utilizing nal (TI) gamma-ray spectrometry and low background alpha/beta counting system. Nuclear Engineering and Technology, S173857332300606X. https://doi.org/10.1016/j.net.2023.12.055.

[4] He, R., Liaw, S., Zhou, M., Zhou, X.-D., & Luo, H. (2022). Environmental evaluation of radioactivity levels and associated radiation hazards in groundwater around the WIPP site. Ecotoxicology and Environmental Safety, 242, 113849. https://doi.org/10.1016/j.ecoenv.2022.113849.

[5] Yehia, M., Baghdady, A., Howari, F. M., Awad, S., & Gad, A. (2017). Natural radioactivity and groundwater quality assessment in the northern area of the Western Desert of Egypt. *Journal of Hydrology: Regional Studies*, *12*, 331–344. https://doi.org/10.1016/j.ejrh.2017.06.002>

[6] Bonotto, D. M. (2019). Gross alpha/beta radioactivity and radiation dose in thermal and non-thermal spas groundwaters. *Heliyon*, *5*(5), e01563. https://doi.org/10.1016/j.heliyon.2019.e01563.

[7] Bashiri, B., Zehtabvar, M., & Shirani, B. (2022). Measurement of Naturally Occurring Radioactive Materials (NORM) in produced water, in some Iranian oil fields using gamma spectroscopy.

[8] Physics Department, College of Education, Mustansiriyah University, Baghdad, Iraq, & Naji Jameel, A. (2023). Radioactivity Levels Determination and Radiological Hazards in the Drink and Well Water Samples in Baghdad. Al-Nahrain Journal of Science, 26(4), 67–72. https://doi.org/10.22401/ANJS.26.4.10.

[9] Ahmed, R. S. (2022). The concentration of radioactive materials in Iraqi soils, water and plants: A review. Journal of Radiation Research and Applied Sciences, 15(1), 245–256. https://doi.org/10.1016/j.jrras.2022.03.012.

[10] Adedokun, M. B., Aweda, M. A., Maleka, P. P., Obed, R. I., & Ibitoye, A. Z. (2022). Evaluation of natural radionuclides and associated radiation hazard indices in soil and water from selected vegetable farmlands in Lagos, Nigeria. Environmental Forensics, 23(3–4), 301–313. https://doi.org/10.1080/15275922.2020.1850557.

[11] Alsofy, D., & Al-jomaily, F. (2022). Estimation of Radionuclides Elements for Natural Water Resources in Nineveh Province, Iraq Using Gamma Ray Spectroscopy. *Arab Journal of Nuclear Sciences and Applications*, *0*(0), 1–13. https://doi.org/10.21608/ajnsa.2022.136383.1576.

[12] Taher, A. A. M., & Mohammad, K. (2020). Natural Radioactivity in Underground Waters In Tallafar Distract In Iraq. *IOP Conference Series: Materials Science and Engineering*, *928*(7), 072079. https://doi.org/10.1088/1757-899X/928/7/072079.

[13] Ononugbo, C., & Tutumeni, G. (2016). Natural Radioactivity and Radiation Dose Estimation in Various Water Samples in Abua/Odua Area, Rivers State, Nigeria. *Physical Science International Journal*, *11*(4), 1–12. https://doi.org/10.9734/PSIJ/2016/28033.

[14] Ahmed, A. M., & Farhan, A. O. (2022). Natural Radioactivity Evaluation and Radiological Peril in some soil specimens of Al-Taimeem Area in Al-Anbar Province, Iraq. *Iraqi Journal of Science*, 182–190. https://doi.org/10.24996/ijs.2022.63.1.19.

[15] Mathuthu, M., Uushona, V., & Indongo, V. (2021). Radiological safety of groundwater around a uranium mine in Namibia. *Physics and Chemistry of the Earth, Parts A/B/C*, *122*, 102915. https://doi.org/10.1016/j.pce.2020.102915.

[16] Ravisankar, R., Sivakumar, S., Chandrasekaran, A., Prince Prakash Jebakumar, J., Vijayalakshmi, I., Vijayagopal, P., & Venkatraman, B. (2014). Spatial distribution of gamma radioactivity levels and

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radiological hazard indices in the East Coastal sediments of Tamilnadu, India with statistical approach. Radiation Physics and Chemistry, 103, 89–98. https://doi.org/10.1016/j.radphyschem.2014.05.037.

[17] Lawal, T. O., Abayomi, S. J., & Oluwakorede Fawale. (2023). Assessment of Activity concentrations of radioactive elements in selected groundwater samples of Kwara State Polytechnic and its environs, North Central Nigeria. Recent Advances in Natural Sciences, 6. https://doi.org/10.61298/rans.2023.1.1.6.

[18] World Health Organization. (2008). Guidelines for drinking-water quality [electronic resource]: Incorporating 1st and 2nd addenda,Vol.1, recommendations (3rd ed). World Health Organization. https://iris.who.int/handle/10665/204411.

[19] El Qassas, R. A. Y., Salaheldin, M., Assran, S. M. A., Abdel Fattah, Th., & Rashed, M. A. (2020). Airborne gamma-ray spectrometric data interpretation on Wadi Queih and Wadi Safaga area, Central Eastern Desert, Egypt. NRIAG Journal of Astronomy and Geophysics, 9(1), 155–167. https://doi.org/10.1080/20909977.2020.1728893.

[20] United Nations (Ed.). (2000). Sources and effects of ionizing radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2000 report to the General Assembly, with scientific annexes. United Nations.

[21] Arabi, A. M. E., Ahmed, N. K., & Salahel Din, K. (2006). Natural radionuclides and dose estimation in natural water resources from Elba protective area, Egypt. Radiation Protection Dosimetry, 121(3), 284–292. https://doi.org/10.1093/rpd/ncl022.

[22] Al-sofy, D. S. M., & Al-Jomaily, F. M. A. (2023). Heat Production Rate and Radiation Hazard Indices from Radioactive Elements in Different Types of Natural Water in Nineveh Governorate, Iraq. Baghdad Science Journal. https://doi.org/10.21123/bsj.2023.7544.