Al-Nahrain Journal of Science
ANJS, Vol. 27(1), March, 2024, pp. 136-142

Assessment of Radioactivity of Some Samples of Healthy Drinking Water and Liquefied Water in Some Areas of the Capital Baghdad Using HPGE Detector System

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Article's Information

Received: 08.11.2023
Accepted: 03.03.2024
Published: 15.03.2024

Keywords:
HPGe detector
Radionuclides
Water
Mineral water
Natural radioactivity

Abstract

In this work, a total of 20 water samples were collected from various locations inside the city of Baghdad. Each sample consists of a volume of 1 litre of water which had been obtained from multiple geographical locations. There were twelve water samples representing pure tap water sourced from various locations additionally, eight samples of mineral water were obtained from several marketplaces in Baghdad. A total of six radionuclides were detected in the water samples using the HPGe detector. These radionuclides were identified as Bi 214, Ra 226, TI 208, Bi 212, Pb 212, and K 40. Among these, Bi 214 and Ra 226 are part of the U-238 series, while TI 208, Bi 212, and Pb 212 belong to the Th 232 series. Additionally, K 40 is a naturally occurring radionuclide. The observed minimum value for the average specific activity of radionuclides in pure tap water samples was Al-Yarmouk Pure tap water. However, the sample Hay Al-qahira pure tap water exhibited the highest recorded specific activity values of radionuclides in pure tap water. The observed minimum value for the average specific activity of radionuclides in mineral water samples was Bardaa mineral water. However, the sample (W15) exhibited the highest recorded values for the specific activity of radionuclides in mineral water. The measured external dosage of natural radioactivity in water samples from Baghdad was found to be relatively low, at 0.366 mSv.y-1. This value falls below the recommended limit the United Nations Scientific Committee set on the Effects of Atomic Radiation (UNSCEAR), 1 mSv.y-1.

https://www.doi.org/10.22401/ANJS.27.1.12

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1. Introduction

Radioactive pollution is a significant and perilous environmental issue that poses escalating risks to living organisms. The utilization of radioactive elements and their prevalence across all domains have led to the exposure of both humans and various forms of flora and fauna [1]. According to the published studies of the World Health Organization, the presence of uranium has been consistently observed in both surface water and groundwater [2]. The quantities of certain substances in water can vary significantly, ranging from 0.01 mg/L to levels surpassing 1500 mg/L. The uranium concentration in water is contingent upon its concentration in the rocks or soil it traverses. The diverse range of human activities associated with manufacturing processes or material utilization can alter the composition of fertilizers employed in those processes [3]. The alteration in the abundance of naturally occurring uranium in water activity encompasses the utilization of phosphates as fertilizers, the efficiency of diverse uranium mining and manufacturing techniques in nuclear fuel facilities, and the applications of depleted uranium in various products [4]. The environment,

encompassing living organisms, materials, air, soil, water, and human-made structures, serves as a crucial medium for human activities aimed at achieving economic growth and prosperity [5]. As long as man remains active and movable in this natural environment, his actions pose risks that negatively impact the environment and pollute it with various pollutants. Pollution is caused by the utilization of technology, which introduces unfamiliar substances into the air, water, or Earth's atmosphere. It has detrimental effects on the quality of resources, resulting in their insufficiency, degradation, or disruption in their utilization [6]. The contamination of the environment by radioactive substances is considered a highly hazardous form of pollution, particularly due to the extensive utilization of nuclear energy and its diverse applications. Nuclear energy has emerged as a fundamental source of generating electricity and an essential enhancer for certain industrial product attributes [7]. Additionally, it is an efficacious factor in mitigating the loss of agricultural commodities and fostering economic prosperity. Animals play a significant role in the preservation of food by preventing rotting. Additionally, they are utilized in the fields of health and medicine for the sake of disease diagnosis and treatment.
This reading aims to measure the activity of the normal radioactive substantial for water samples of Baghdad city consuming HPGe detector and compare between the pure tap water samples and mineral water. Equation (1) is utilized to quantify the external dose for all radionuclides [8]:

$$D\ (\mu\ Sv.h^{-1}) = 0.0007\ (0.462C_{Ra} + 0.604C_{Th} + 0.0417C_K) + 0.034 \quad \ldots(1)$$

$$D = 0.366\ m\ Sv.h^{-1} \quad \ldots(2)$$

2. Materials and Methods

A total of twenty water samples were collected from various locations inside. The samples consisted of twelve samples of pure tap water collected from various regions of Baghdad, as shown in Figure (1). A total of eight samples of mineral water were bought from various marketplaces in Baghdad, with each sample consisting of one liter.

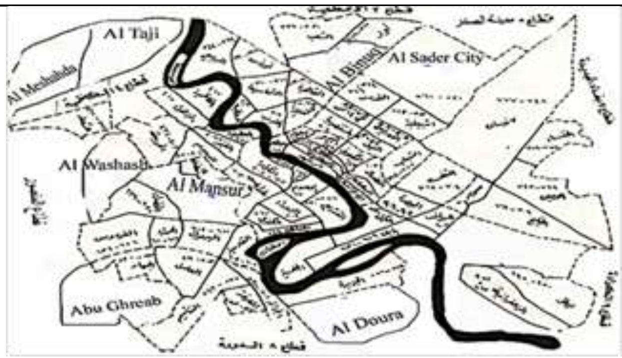

Figure 1. Some areas of Baghdad city

In total, water samples were retained within the laboratory in order to assess their radiological equilibrium. The samples were stored at a controlled laboratory temperature of 22±2°C, which is within the range of room temperature. The samples were stored in a controlled environment within the laboratory, shielded from sunlight and other external factors, for a duration of approximately one month. This was done to ensure the establishment of radiation equilibrium and the complete dissolution of radon gas. The laboratory's radiation background, which was influenced by prevailing weather conditions, was quantified, documented, and afterwards deducted from the obtained measurements.

Table 1. The codes of altogether water samples

Code of sample	Type of water samples
W1	Karrada Pure tap water
W2	Al-Jamaa Pure tap water
W3	Baghdad Aljadida Pure tap water
W4	Al-Jadiriyah Pure tap water
W5	Alhuriya Pure tap water
W6	Dora Pure tap water
W7	AlMashtal Pure tap water
W8	Al-Yarmouk Pure tap water
W9	Al Doulai Pure tap water
W10	Abu Ghraib Pure tap water
W11	AlDubaati- Hay Al-Jihad Pure tap water
W12	Hay Alqahira Pure tap water
W13	Al wafi mineral water
W14	Al raawia mineral water
W15	Al-Sad mineral water
W16	Bardaa mineral water
W17	Al muzn mineral water
W18	Talia mineral water
W19	Aquafina mineral water
W20	Al kawthar mineral water

3. Experimental details

Eliminating contaminants in the liquid state is a critical aspect of the production process. Subsequently [9]. The material undergoes a phase transition to a frozen state, wherein impurities are effectively removed, producing a highly purified.

Figure 2. HPG detector with case and monitor

To Form a pure Germanium crystal, it is important to decrease the concentration of contaminants inside the crystal to 1010 atoms per cm3. Therefore, achieving a layer thickness of up to 15 mm is possible at a counter-voltage equivalent to approximately 1000 volts. Subsequently, these crystals can substitute Ge (Li) crystals. The crystals can be stored at room temperature due to their absence of lithium content. Regarding operational conditions, conducting operations at a temperature of 77 Kelvin (K) is seen as more favorable. However, it is feasible to carry out operations within a temperature range of 150 to 180 K. Hence, these gadgets can be stored and reactivated multiple times without significant issues. The detector consists of a crystal of pure Germanium, exhibiting a positive pattern [10]. Subsequently, a small quantity of lithium is evaporated onto a specific surface of the crystal, forming a negative-type layer that serves as an electrical connection denoted as (+n). Subsequently, a modest increase in temperature is applied to facilitate the diffusion of lithium ions into the germanium crystal. When a reverse voltage is applied to the positive-negative junction, it creates an unoccupied region known as the sensitive volume of the detector. The opposite extremity of the crystal is reinforced and affixed to a metal material that possesses appropriate electrical conductivity properties, thereby serving as a positive layer (P+). A detector can be engineered to encompass the entirety of the positive sector within the crystal, resulting in total depletion of the detector. This configuration allows for the attainment of the maximum achievable volume. The overall system specifications are presented in Table 2 [11].

Table 2. General specifications of Canberra system.

System	The specifications
detector sort	Semiconductor, Ge
Crystal Volume	3×3 inch
Gas	Liquid Nitrogen at 77 K
Operating voltage	-2500 V dc
No. of channel	(4096) ch.
FWHM for (Co-60)	1.33 MeV
Relative efficiency	20 %
Counting time for each sample	2h.
Resolution	2 keV
Diameter of crystal	6 cm
Length of crystal	5 cm
Distance from the window	0.5 cm
Detector typical	G 3020
Cryostat typical	7500 SL

4. Results and Discussion

Table No. 3 and Table No. 4 were created separately in order to distinguish between pure tap water and the mineral samples, as below: Six radionuclides were detected using an HPGe detector; which explain the maximum and minimum value of this specific activity of 12 samples of pure tap water is exposed in Table 3.

Table 3. The specific activities of pure tap water samples

samples	Bi 214 Bq/L	Ra 226 Bq/L	Tl 208 Bq/L	Bi 212 Bq/L	Pb 212 Bq/L	K^{40} Bq/L
W1	4.54	4.80	2.90	3.80	1.46	181
W2	4.22	4.95	2.80	4.10	1.47	188
W3	4.60	5.64	2.75	4.30	2.10	184
W4	4.90	5.11	2.70	3.44	2.14	192
W5	5.33	5.67	2.54	4.10	2.16	198
W6	5.66	6.48	2.66	3.66	2.20	184
W7	5.21	6.33	2.62	3.58	2.11	196
W8	4.21	4.36	2.50	3.20	1.20	180
W9	4.55	7.41	3.18	3.25	1.30	195
W10	4.62	7.55	3.11	3.55	1.44	194
W11	4.66	7.32	3.12	4.22	1.22	185
W12	6.40	7.92	3.20	5.50	2.22	230
Minimum value	4.21	4.36	2.50	3.20	1.20	180
Maximum value	6.40	7.92	3.20	5.50	2.22	230
Average	4.90	6.12	2.84	3.89	1.75	192.25

Six radionuclides remained strained to apply the HPGe detector; which explain the maximum and minimum value of the specific activities of the mineral samples are revealed in Table 4.

Table 4. The specific activities of radionuclides water samples

samples	Bi 214 Bq/L	Ra 226 Bq/L	Tl 208 Bq/L	Bi 212 Bq/L	Pb 212 Bq/L	K 40 Bq/L
W13	2.50	5.80	2.38	4.54	1.64	155
W14	2.40	5.35	2.36	4.20	1.55	174
W15	2.80	6.70	3.10	4.90	2.00	190
W16	2.00	5.20	2.30	3.00	1.00	150
W17	2.15	5.30	2.80	3.20	1.24	166
W18	2.44	6.20	3.00	3.60	1.45	170
W19	2.50	6.40	2.90	3.55	1.22	185
W20	2.60	6.33	2.60	3.84	1.44	184
Minimum value	2.00	5.20	2.30	3.00	1.00	150
Maximum value	2.80	6.70	3.10	4.90	2.00	190
Average	2.42	5.91	2.68	3.85	1.44	171.25

The specific activities for the water samples remain exposed in Table 5.

Table 5. The specific activities of altogether samples

samples	Bi 214 Bq/L	Ra 226 Bq/L	Tl 208 Bq/L	Bi 212 Bq/L	Pb 212 Bq/L	K 40 Bq/L
W1	4.54	4.80	2.90	3.80	1.46	181
W2	4.22	4.95	2.80	4.10	1.47	188
W3	4.60	5.64	2.75	4.30	2.10	184
W4	4.90	5.11	2.70	3.44	2.14	192
W5	5.33	5.67	2.54	4.10	2.16	198
W6	5.66	6.48	2.66	3.66	2.20	184
W7	5.21	6.33	2.62	3.58	2.11	196
W8	4.21	4.36	2.50	3.20	1.20	180
W9	4.55	7.41	3.18	3.25	1.30	195
W10	4.62	7.55	3.11	3.55	1.44	194
W11	4.66	7.32	3.12	4.22	1.22	185
W12	6.40	7.92	3.20	5.50	2.22	230
W13	2.50	5.80	2.38	4.54	1.64	155
W14	2.40	5.35	2.36	4.20	1.55	174
W15	2.80	6.70	3.10	4.90	2.00	190
W16	2.00	5.20	2.30	3.00	1.00	150
W17	2.15	5.30	2.80	3.20	1.24	166
W18	2.44	6.20	3.00	3.60	1.45	170
W19	2.50	6.40	2.90	3.55	1.22	185
W20	2.60	6.33	2.60	3.84	1.44	184
Average	3.91	5.84	2.77	3.87	1.68	184.05

The specific activities for Bi 214 in all samples are exposed in Figure (3).

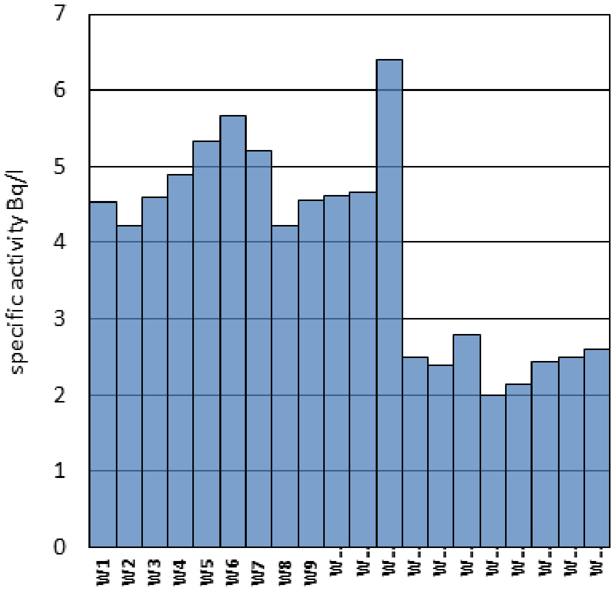

Figure 3. The specific activities for Bi 214 in altogether samples.

The specific activities for Ra 226 in all samples are exposed in Figure (4).

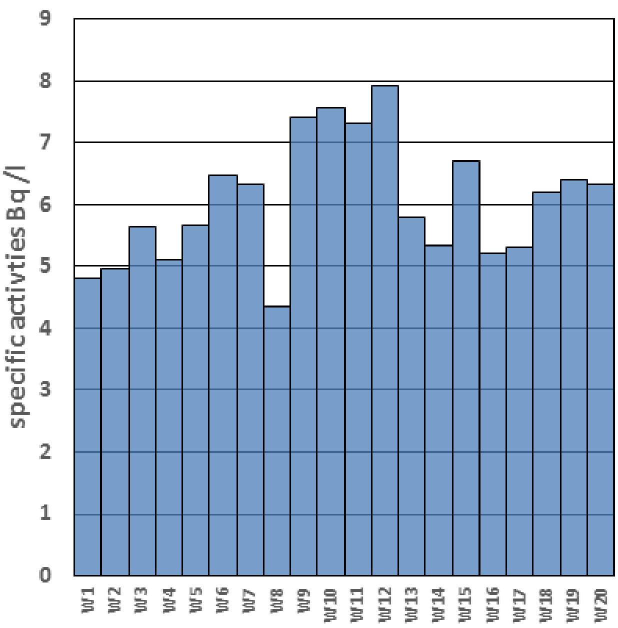

Figure 4. The specific activities for Ra226 in altogether samples.

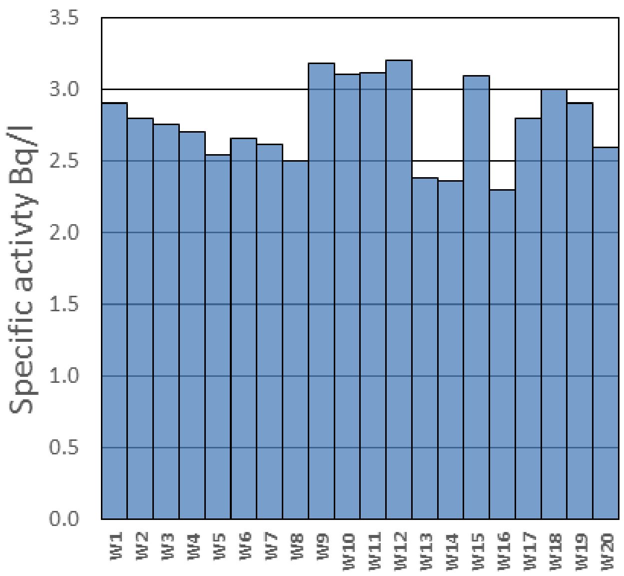

Figure 5. The specific activities for Tl 208 in altogether samples.

The specific activities for Bi 212 in all samples are exposed in Figure 6.

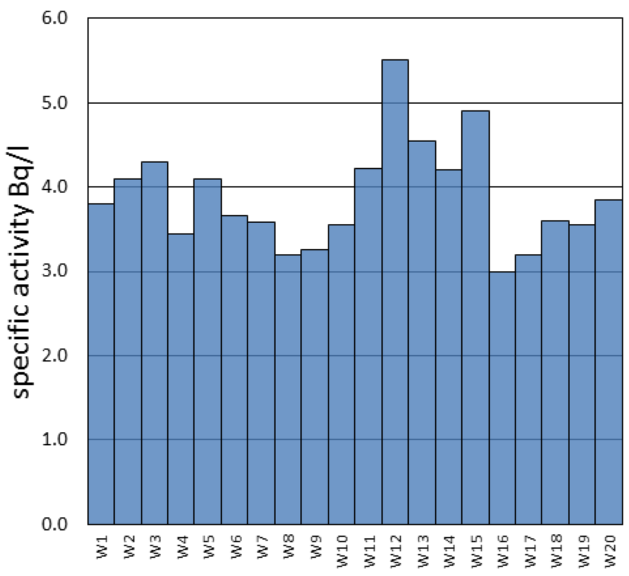

Figure 6. The specific activities for Bi 212 in altogether samples.

The specific activities for Pb 212 in all samples are exposed in Figure 7.

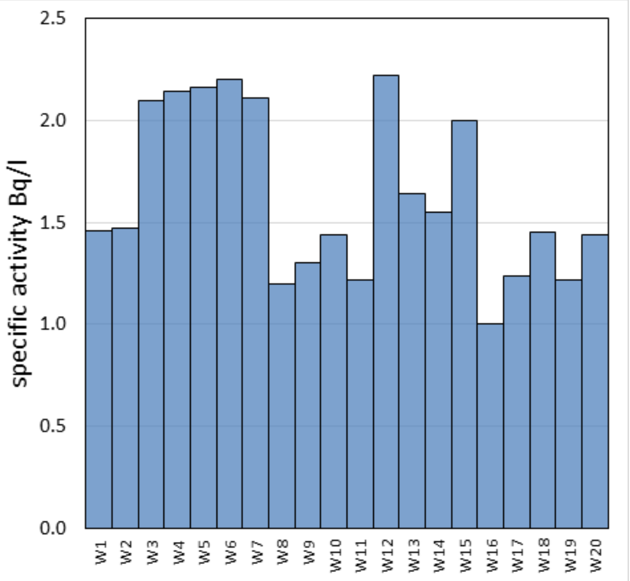

Figure 7. The specific activities for Pb 212 in altogether samples.

The specific activities for K 40 in all samples are exposed in Figure 8.

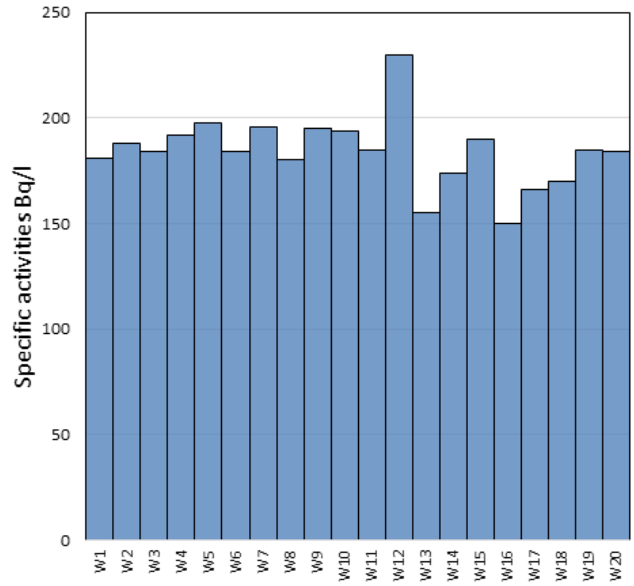

Figure 8. The specific activities for K 40 in altogether samples.

The average of specific activities in all the radionuclides in Baghdad samples are exposed in Figure 9.

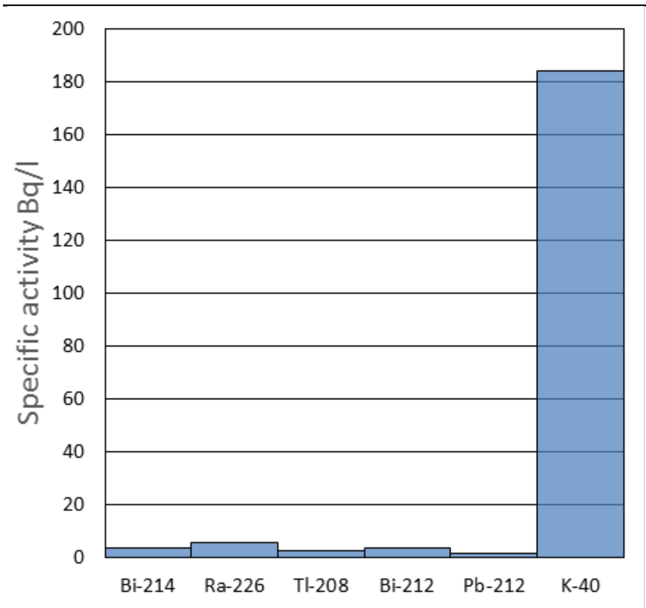

Figure 9. The average of activity in altogether the radionuclides.

The radioactive spectrum of a water sample, obtained in this study and analyzed using a High-Purity Germanium HPGe is shown in Figure 10.

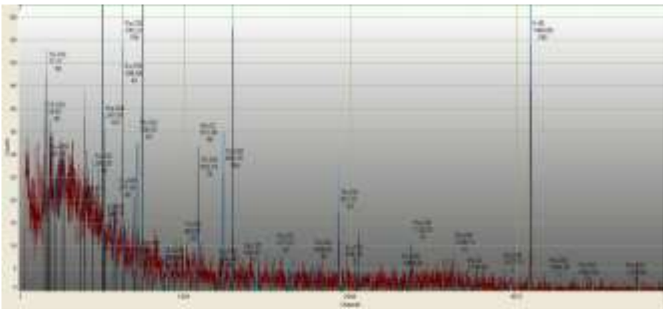

Figure 10. The spectrum of one sample within HPGe detector.

5. Conclusions

In Table 2 it can be observed that the minimum specific activity of Bi 214 was recorded as 4.21 Bq/L during sample W8 Conversely, the maximum specific activity of 6.40 Bq/L was observed durinW12. The average specific activity was calculated to be 4.90 Bq/L. The least specific activity value of Ra 226 was observed to be 4.36 Bq/L for sample W8. Conversely, the maximum specific activity value of 7.92 Bq/L was recorded for sample W12. The average specific activity across all samples was 6.12 Bq/L. The specific activities of Tl 208 exhibited the lowest value of 2.50 Bq/L for sample W8. Conversely, the greatest value of specific activities was 1.22 Bq/L for sample W12. The average specific activity across all samples was calculated to be 2.84 Bq/L. The minimal specific activity of Bi 212 was observed to be 3.20 Bq/L at W8, while the maximum specific activity was recorded as 5.50 Bq/L at W 12. The average specific activity for the entire period was 3.89 Bq/L.

The specific activities of Pb 212 exhibited a minimal value of 1.2 Bq/L at W8. Conversely, the maximum value of specific activities was seen during W12, measuring 2.22 Bq/L. The average specific activity over the entire period was calculated to be 1.75 Bq/L. The minimal specific activity of K-40 was observed to be 180 Bq/L at week 8, while the greatest specific activity recorded was 230 Bq/L at W 12.

The average specific activity during the entire period was calculated to be 192.25 Bq/L. Table 4 shows that the lowest recorded value for the specific activities of Bi 214 was 2.00 Bq/L, which occurred during (W16). Conversely, the highest recorded value for specific activities was 2.80 Bq/L, observed during (W15). On average, the specific activities of Bi 214 were found to be 2.42 Bq/L.

The lowest recorded specific activity of Ra 226 was 5.20 Bq/L for W16, while the highest recorded specific activity was 6.70 Bq/L for W12, with an average of 5.91 Bq/L. The specific activities of Tl 208 exhibited a minimum value of 2.30 Bq/L for the sample labelled as W16. Conversely, the maximum value of specific activities was observed in the sample denoted as W15, with a measurement of 3.10 Bq/L. The average specific activity across all samples was calculated to be 2.68 Bq/L. The lowest recorded specific activity of Bi 212 was 3.00 Bq/L during W16, while the highest recorded specific activity was 4.90 Bq/L during W15. On average, the specific activity of Bi 212 was 3.85 Bq/L.

The minimum recorded value for the particular activity of Pb 212 was 1.00 Bq/L during (W16). The sample (W15) had the highest specific activity value of 2.00 Bq/L, while the average specific activity for all samples was 1.44 Bq/L. The lowest recorded specific activity of K-40 was 150 Bq/L during week 16, while the highest recorded specific activity was 190 Bq/L during W 15. The average specific activity overall samples was 171.25 Bq/L. In Figure 9, the lowest average specific activity observed among all radionuclides in all samples was for Pb-212, measuring 1.75 Bq/L. Conversely, the highest average specific activity observed among all radionuclides in all samples was for K-40, measuring 192.25 Bq/L.

The findings of this study indicate that packed, and commercially available water samples in local markets had lower levels of natural radioactivity compared to some areas inside the city of Baghdad. The collected samples from the water stations exhibited a higher presence of mud sediments, sand, and salts. This can be attributed to the extensive water extraction from the stations and its continuous distribution to the public. Based on the findings, the researchers anticipated and subsequently verified that the conditions at each station vary in terms of the water type produced by the respective station. Variations were observed among the water stations dispersed across the urban center of Baghdad, as well as discrepancies in the levels of radioactivity detected in the samples included within the city of Baghdad. Our research revealed that the concentrations of natural potassium isotope K-40 were the highest among all the observed concentrations. Conversely, the concentrations of lead isotope Pb-212 were found to be the lowest. It is well-known that an increase in the proportion of lead in natural samples is indicative of high radiation concentrations. However, we did not observe such an increase in our collected samples. Additionally, we did not detect the presence of the Cs-137 element in our samples. The external dose of natural radioactivity in the water samples collected in this study was determined to be 0.366 mSv.y-1. Our findings indicate that the radioactive concentrations in mineral water were lower compared to those in raw water. This disparity can be attributed to the water sources being connected to areas with old pipes, as well as the presence of mud precipitation and salts, which have contributed to the observed increase in radioactive concentrations. This levels of natural radioactivity in water samples are quite low when compared to the permissible limit of 1 mSv.y-1. [12, 13].

Funding: This research is self-funded.

Conflict of Interest: The authors declare no conflict of interest.

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