وقائع المؤتمر العلمي السنوي الثالث لكلية التربية الاساسية
في مجال العلوم الصرفة والموسوم:
(مؤتمر كلية التربية الاساسية في مجال العلوم الصرفة)
وتحت شعار
(بالعلوم الصرفة نبني واقعا معرفيا متجددا)
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Assessment of External Gamma Dose Rates and Radiological Contamination in Iraqi Water Sources

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Abstract

An extensive radiological analysis was performed on 50 samples in total, 25 samples of common tap water and 25 commercial mineral water samples, which were selected in the different local markets and cities in Iraq, to be analyzed properly and in standard polypropylene beakers. To examine the possible variation of behavior of radionuclides to determine whether or not there was any change, three main parameters, that is, the Surface Contamination (Bq/cm^2), the Dose rate (µSv/h), and the General Count Rate (Cps) were measured using a portable RadEye B20 survey detector in two states namely the as-collected state and the controlled boiling state. The researchers concluded that mineral water displayed slightly lower mean radiological parameters than tap water where mean values pre-boiling included Tap Water 0.295 (Bq/cm^2), 0.205 (µSv/h), and 0.509 (Cps) whereas means before boiling was Mineral Water 0.275 (Bq/cm^2), 0.185 (µSv/h), and 0.469 (Cps). The statistically insignificant effect on subsequent detector readings was the effect the boiling process had which was within the internal error/sensitivity range of the instrument. Finally, all the water samples produced very low radiological results thus coming to the concluding that both tap and mineral water usage in the analyzed areas of Iraq represent non-significant radiological concern to the human health condition since all the

radiological parameters of all samples were much lower than the recommended international intervention norms.

Keywords: radiological analysis, Dose rate, Surface Contamination, tap water, mineral water, RadEye B20.

1. Introduction

Safe and affordable drinking water is a major citizen health issue, especially in places like Iraq where domestic water supply is mainly through the municipal taps as a major source of drinking water since the bottled mineral water may be too costly to the average population (Noubactep, 2011). To this end it is stated that the determination of the naturally occurring radionuclide levels in both tap and mineral water is very beneficial in the field of environmental restoration and research on human health (Salih, Pettersson and Lund, 2002). Therefore, such water sources need to be strictly examined to ascertain that there is no possibility of finding radioactive contamination and radiological risks involved (Surbeck, 1995). Mineral radioactive isotopes of the natural decay sequence: the Uranium-238, Thorium-232, Potassium-40 chains and their halogens as well as the objects that produced them are well conditioned by localities in geology and the kind of water used (Karahan, 2000)**,** (Pelić et al., 2023). According to recommendations of the World Health Organization (WHO), the consumption of water is radiologically safe, if one does not consume more than two liters of water per day (World Health Organization, 1998).

Even though local people have not stated significant challenges in health that are directly linked to tap water contamination, there may be a threat to health in the future due to the accumulated impacts of prolonged low-level exposure (Shakoor et al., 2017). Since tap and mineral water are used daily, there is enough reason to measure and confirm three main radiological safety parameters such as dose rate, surface contamination, and overall count rate, daily (Baqir and Kadhim, 2020). The importance of this undertaking is indicated by the international researches, which have investigated the radioactivity of tap and mineral waters in many countries, including South America (Bonotto, 2004), Croatia (Marović et al., 1996), Spain (Kralik, Friedrich and Vojir, 2003), Austria (Tanigava, 2001), Brazil (Lauria and

Godoy, 2002), and Hungary (Somlai et al., 2002) but multiple studies have only focused on the specific radiological parameters.

The transportable RadEye B20 detector is used in this research to measure doses of radiation around the samples and inside the working environment (Shahbazi-Gahrouei, Gholami and Setayandeh, 2013), where the overall count rate (cps) is continuously shown to notify the user of the current level of conditions in counting (Thermo Scientific, 2017). One of the main assumptions on this investigation is the conjecture that boiling water will not decline or evade quantifiable surface contamination and dose rate or count rate (Juran and MacDonald, 2014); thus, in the event that radioactive material like U -238, Th -232, have K -40 or any of their decays are present, the readings on the detector will be identical irrespective of boiling, provided that the inherent measurement error and sensitivity of the apparatus (Hassan et al., 2016)**,** (Kadhim and Omran, 2019) and (Seco, Clasie and Partridge, 2014).

2. Materials and methods

2.1. Samples Collection and preparation

Overall, this study involved 50 water samples that are analyzed, including 25 Municipal Tap Water Samples collected in the different cities of Iraq, in the municipal water supply systems, and 25 Commercial Mineral Water Samples, which were bought at local markets in the same locations. All samples were first pipet samples into clean, standardized polypropylene beakers and tightly closed to maintain the integrity before further analysis. In analyzing the impact of common domestic processing on radiological measurements, each sample was prepared in two conditions (1) the Normal (As‑Collected) State to serve as a baseline sample and (2) the Boiled State whereby an aliquot of a sample was boiled (controlled boiling, maintained at 100 ^{o}C with 15 minutes) then allowed to cool down to ambient temperature so it can be re-measured in a standardized beaker.

This two-way preparation will allow strict testing of the hypothesis that boiling has no strong effect on the concentration of soluble radionuclides (U -238, Th -232, K -40 and their decay products) and, by extension, does not influence the measurements in the external RadEye B20 detector.

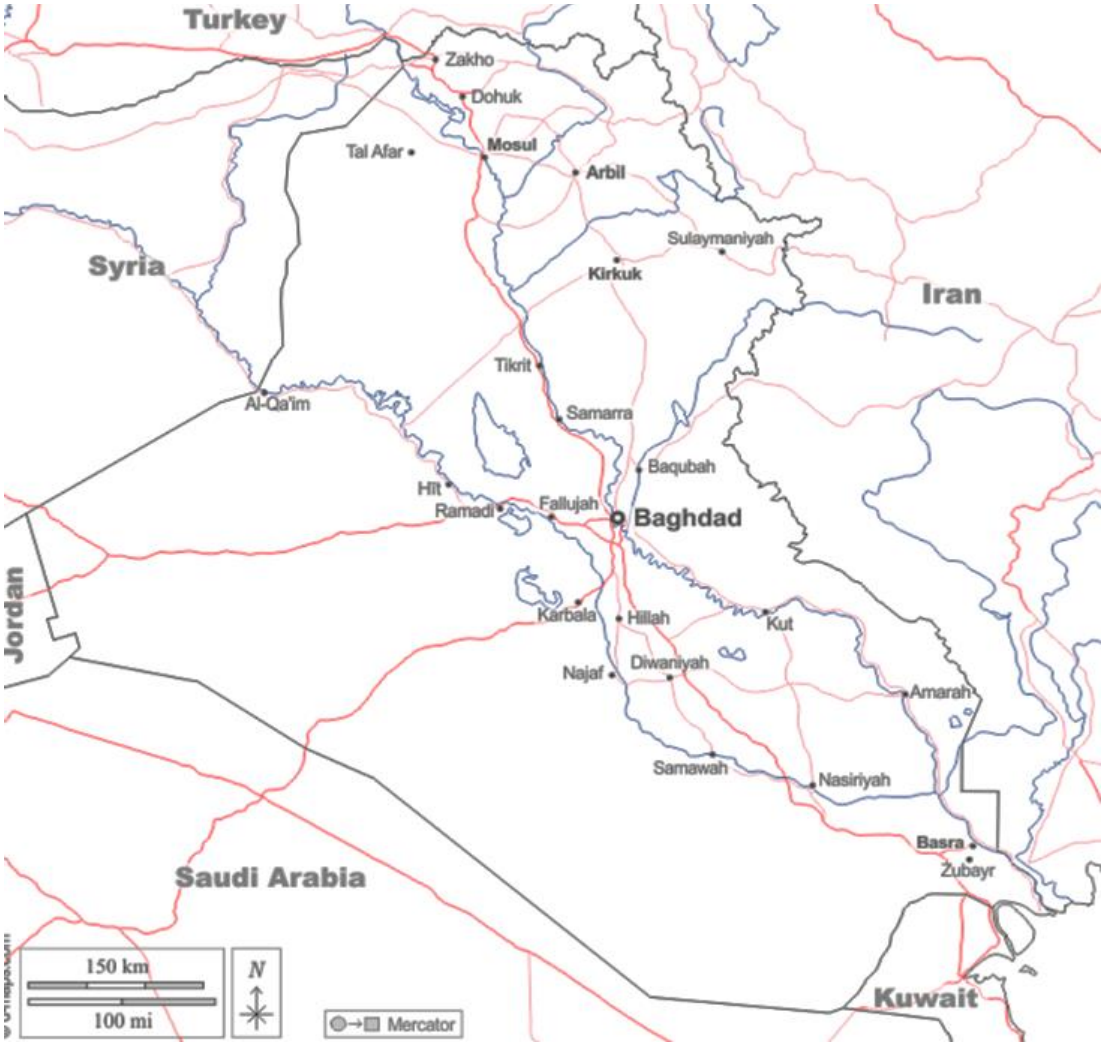


Figure 1 Geographical coverage of the sampled tap and mineral water. (d-maps.com, n.d.-2025)

Table 1 Governorate samples, location and codes of water.

Province	Region	Samples		
		Tap water	Mineral water	
		code	Simple name	code
Baghdad	Zayouna	T.1	Alrawa	M.1
	Adhamiya	T.2	Pearl	M.2
	Al-Mansour	T.3	Alrawasi	M.3
	Al-Fahhama	T.4	Rawea	M.4
	Al-Sader City	T.5	Rim	M.5
Basrah	Abu Al-Khasib	T.6	Khor	M.6
	Al-Zubair	T.7	Kafeel	M.7
Hilla	Old Hilla	T.8	Kawthar	M.8
	Fadak	T.9	Dinar	M.9
Diwaniyah	Al-Daghara	T.10	Wareth	M.10
	Al-Shamiya	T.11	Wafi	M.11
Wasit	Kuot	T.12	Aquafina	M.12
	Essaouira	T.13	Afiat/Oyoun	M.13
Nasiriyah	Al-Saray	T.14	AL ain	M.14
	Eridu	T.15	Masafi	M.15
Maysan	Al-Marjar	T.16	Hanaa	M.16
	Al-Kahla	T.17	Helwa	M.17
Karkuk	Daquq	T.18	313	M.18
	Hawija	T.19	Naqaa	M.19
Dohuk	Amadiya	T.20	Life	M.20
	Zakho	T.21	Alyanabie	M.21
Muthanna	Al-Rumaitha	T.22	Forat	M.22
	Al-Khadir	T.23	Barada	M.23
Samarra	Al-Mu'tasim	T.24	Alsuhoul	M.24
	Al-Tharthar	T.25	Crystal	M.25

2.2. RadEye B20 detector

Radioactive contamination was measured in the low-level radiations using a highly sensitive RadEye B20 digital meter, integrating a detector of germanium-tube (usually known as Pancake Geiger-Muller or other similar high-sensitivity design in RadEye series). Measurements were based on two parameters, namely the gamma dose rate and count rate per second (Cps). The instrument was set to measure gamma dose rates in an energy range of 17-1300 keV, and applied an optional gamma energy filter, such that the measured dose equivalent would be accurately defined in this wide range. In every case of radiological testing, samples were placed in a set of standardized polypropylenes (PP) beakers, and RadEyeB20 detector was put on the sampling surface itself. Measurements were all conducted with three minutes constant integration to ensure sufficient integration period to make use of reliable counting statistics at the low level of radiation of the environmental samples.



Figure 2 Instruments and samples.

Results and discussion

The radiological analysis of tap and mineral water samples showed that all activities measured were consistently low, which represented the radiological negligence. The highest registered values of the tap water samples, which were recorded in sample T.10 and T.22, were; 0.32 and 0.23 Bq/cm^2 (surface contamination), 0.23 and 0.22 µSv/h (dose rate) and 0.56-0.54 Cps (count rate), respectively, before the boiling process. The same, the maximum values of mineral water were in samples M.10, and M.16, with 0.30 to 0.29 Bq/cm^2, 0.21 to 0.20 µSv/h and 0.52 to 0.50 Cps respectively. On the other hand, the tap water sample T.1 associated with 0.26 Bq/cm^2, 0.17 µSv/h, and 0.44 Cps showed the lowest activity. The lowest activity mineral water was M.2, at 0.24 Bq/cm^2, 0.15 µSv/h and 0.40 Cps, which was summarized in Table 2. Radiological analysis of the samples of water was conducted with the aid of RadEye B20 portable detector after boiling and evaporation pretreatment.

Boiling expels radioactive Radon gas and precipitates minerals due to reduced solubility, causing an immediate drop in detector readings.

This reflects a transfer of radioactivity to the air or sediment rather than its disappearance, resulting in a "degassed" sample.

This procedure was intended to measure the number of radionuclides deposited as residue at low level of volatility hence transforming low-level volumetric activity into quantifiable surface contamination through a concentration effect.

The findings reveal a steady in all the parameters of activity in comparison with the set levels of the background contamination (0.24 Bq/cm^2) as well as the dose rate (0.15 µSv/h). The tap water had a mean surface contamination of 0.286 Bq/cm^2 and the mineral water had a surface contamination of 0.268 Bq/cm^2, which confirmed the existence of non-volatile radioisotopes that can be detected in both tap water and mineral water, including elements of the naturally occurring uranium and thorium decay series.

The RadEye B20 detects radioactive isotopes indirectly by monitoring the (CPS) above normal levels, rather than through spectroscopic analysis. The

type of isotope is then logically inferred by observing the effect of physical factors (such as barriers and boiling) on the intensity of the reading.

Moreover, tap water had slightly meaner dose rate and count rate per second (0.196 µSv/h and 0.491 Cps, respectively) as compared to the mineral water (0.178 µSv/h and 0.456 Cps). The highest Cps recorded was 0.54 in the tap water (in Al-Shamtiya and Al-Rumaytha) and 0.52 in the mineral water (in Al-Daghba, Al-Shamtiya and Al-Marjar). This mathematical increase of activity relative to the background proves the effectiveness of the concentration method and indicates a somewhat increased average concentration of fixed residue in the public supply of tap water but otherwise the radiologic values are generally low (Table 3).

Table 2 Before boiling, location, codes of water samples and measurements of RadEye B20.

Region	Tap Water code	Mineral water code	RadEye B20 measurements					
			Surface contamination (Bq/cm^2)		Dose rate (µSv/h)		Count rate per second (Cps).	
			Tap Water	Mineral water	Tap Water	Mineral water	Tap Water	Mineral water
Zayyouna	T.1	M.1	0.26	0.27	0.17	0.18	0.44	0.46
Al-Adhamiya	T.2	M.2	0.29	0.24	0.2	0.15	0.5	0.4
Al-Mansour	T.3	M.3	0.27	0.27	0.18	0.18	0.46	0.46
Al-Fahhama	T.4	M.4	0.3	0.28	0.21	0.19	0.52	0.48
Al-Sader City	T.5	M.5	0.29	0.27	0.2	0.18	0.5	0.46
Abu Al-Khasib	T.6	M.6	0.31	0.29	0.22	0.2	0.54	0.5
Al-Zubair	T.7	M.7	0.3	0.28	0.21	0.19	0.52	0.48
Old Hilla	T.8	M.8	0.29	0.27	0.2	0.18	0.5	0.46
Fadak	T.9	M.9	0.3	0.28	0.21	0.19	0.52	0.48
Al-Daghara	T.10	M.10	0.29	0.3	0.2	0.21	0.5	0.52
Al-Shamiya	T.11	M.11	0.32	0.28	0.23	0.19	0.56	0.48
Kuot	T.12	M.12	0.3	0.25	0.21	0.16	0.52	0.42
Essaouira	T.13	M.13	0.29	0.26	0.2	0.17	0.5	0.44
Al-Saray	T.14	M.14	0.3	0.29	0.21	0.2	0.52	0.5
Eridu	T.15	M.15	0.28	0.26	0.19	0.17	0.48	0.44
Al-Majar	T.16	M.16	0.28	0.29	0.19	0.2	0.48	0.5

Al-Kahla	T.17	M.17	0.3	0.28	0.21	0.19	0.52	0.48
Daquq	T.18	M.18	0.31	0.29	0.22	0.2	0.54	0.5
Hawija	T.19	M.19	0.29	0.26	0.2	0.17	0.5	0.44
Amadiya	T.20	M.20	0.28	0.27	0.19	0.18	0.48	0.46
Zakho	T.21	M.21	0.31	0.29	0.22	0.2	0.54	0.5
Al-Rumaitha	T.22	M.22	0.31	0.26	0.22	0.17	0.54	0.44
Al-Khadir	T.23	M.23	0.29	0.27	0.2	0.18	0.5	0.46
Al-Mu'tasim	T.24	M.24	0.31	0.29	0.22	0.2	0.54	0.5
Al-Tharthar	T.25	M.25	0.28	0.26	0.19	0.17	0.48	0.44
Maximum			0.32	0.3	0.23	0.21	0.56	0.52
minimum			0.26	0.24	0.17	0.15	0.44	0.4
mean			0.295	0.275	0.205	0.185	0.509	0.469
Background			0.24		0.15		0.40	

Table 3 Water sample location, sample codes and RadEye B20 after boiling.

location	Tap Water code	Mineral water code	RadEye B20 measurements					
			Surface contamination (Bq/cm^2)		Dose rate (µSv/h)		Count rate per second (Cps).	
			Tap Water	Mineral water	Tap Water	Mineral water	Tap Water	Mineral water
Zayyouna	T.1	M.1	T.1	0.26	0.16	0.17	0.42	0.44
Al-Adhamiya	T.2	M.2	T.2	0.24	0.19	0.15	0.48	0.4
Al-Mansour	T.3	M.3	T.3	0.26	0.17	0.17	0.44	0.44
Al-Fahhama	T.4	M.4	T.4	0.27	0.2	0.18	0.5	0.46
Al-Sader City	T.5	M.5	T.5	0.25	0.19	0.16	0.48	0.42
Abu Al-Khasib	T.6	M.6	T.6	0.27	0.21	0.18	0.52	0.46
Al-Zubair	T.7	M.7	T.7	0.26	0.2	0.17	0.5	0.44
Old Hilla	T.8	M.8	T.8	0.27	0.2	0.18	0.5	0.46
Fadak	T.9	M.9	T.9	0.26	0.19	0.17	0.48	0.44
Al-Daghara	T.10	M.10	T.10	0.3	0.21	0.21	0.52	0.52
Al-Shamiya	T.11	M.11	T.11	0.27	0.22	0.18	0.54	0.46
Kuot	T.12	M.12	T.12	0.25	0.2	0.16	0.5	0.42
Essaouira	T.13	M.13	T.13	0.26	0.19	0.17	0.48	0.44
Al-Saray	T.14	M.14	T.14	0.27	0.18	0.18	0.46	0.46
Eridu	T.15	M.15	T.15	0.28	0.2	0.19	0.5	0.48

Al-Marjar	T.16	M.16	T.16	0.29	0.19	0.2	0.48	0.5
Al-Kahla	T.17	M.17	T.17	0.26	0.2	0.17	0.5	0.44
Daquq	T.18	M.18	T.18	0.28	0.21	0.19	0.52	0.48
Hawija	T.19	M.19	T.19	0.27	0.19	0.18	0.48	0.46
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Zakho	T.21	M.21	T.21	0.29	0.21	0.2	0.52	0.5
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Al-Mu'tasim	T.24	M.24	T.24	0.28	0.2	0.19	0.5	0.48
Al-Tharthar	T.25	M.25	T.25	0.26	0.18	0.17	0.46	0.44
Maximum			0.31	0.29	0.22	0.21	0.54	0.52
minimum			0.25	0.24	0.16	0.15	0.42	0.4
mean			0.286	0.268	0.196	0.178	0.491	0.456
Background			0.24		0.15		0.40	

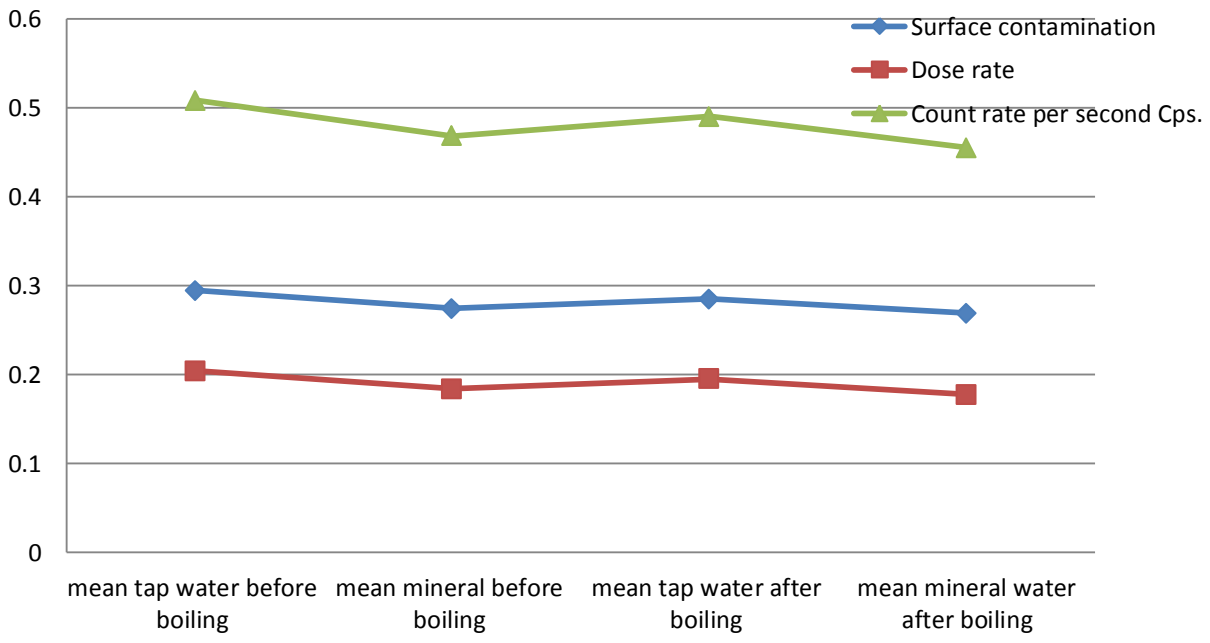


Figure 3 Mean values of complete samples before and after boiling.

Conclusion

Comparative evaluation of radiological measurements surface contamination, dose rate and counts per second (Cps) measurements taken on water samples before and after boiling gives essential clues to the definition of the radioactivity, which has been identified. Prior to testing, it was discovered that the tap and the mineral water had a surface contamination level of 0.295 and 0.275 Bq/cm^2 respectively with dose rates of 0.205 and 0.185 µSv/h respectively. These values were a little higher than the background and represent an activity of both non residual and volatile radionuclides that existed in the liquid phase. The experimental results showed that the average surface contamination of tap water fell slightly, due to the boiling treatment, to 0.286 Bq/cm^2. There were also slight decreases in the mean dose rate and Cps of the tap water (0.205 to 0.196 µSv/h and 0.509 to 0.491 Cps, respectively). Most of the non-volatile activity remained in the residue which was proved by the relatively high Cps of 0.491 of tap water and 0.456 of mineral water at the end of boiling, compared to background. Therefore, the activity of the predominant source in the raw samples can be attributed to the radionuclides that are nonvolatile.

Finally, the obtained Cps and dose rates of the concentrated residue are near to the common background rates of the radiological isotopes in the environment, which means that the amount of the radiological contamination risk in terms of which the non-volatile isotopes of the water sources investigated are observed to be small and fall within standard safe levels.

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المستخلص:
تم إجراء تحليل إشعاعي شامل على 50 عينة إجمالا، و25 عينة من مياه الصنبور الشائعة و25 عينة تجارية من المياه المعدنية، تم اختيارها في الأسواق المحلية والمدن المختلفة في العراق، ليتم تحليلها بشكل صحيح وفي كؤوس البولي بروبيلين القياسية. لفحص التغيرات المحتملة في سلوك النويدات المشعة لتحديد ما إذا كان هناك أي تغيير، تم قياس ثلاثة معايير رئيسية، وهي: التلوث السطحي (Bq/cm2)، ومعدل الجرعة (µSv/h)، ومعدل العد العام (Cps) باستخدام كاشف مسح RadEye B20 المحمول في حالتين، وهما الحالة المجمعة والحالة المغلية المسيطر عليها. خلص الباحثون إلى أن المياه المعدنية أظهرت متوسط معايير إشعاعية أقل قليلا من مياه الصنبور حيث شملت القيم المتوسطة قبل الغليان ماء الصنبور 0.295 (Bq/cm2)، 0.205 (µSv/h)، و0.509 (Cps)، بينما كان متوسط المياه المعدنية قبل الغليان 0.275 (Bq/cm2)، 0.185 (µSv/h)، و0.469 (Cps). التأثير غير المهم إحصائيا على قراءات الكاشف اللاحقة كان تأثير عملية الغليان التي تقع ضمن نطاق الخطأ/الحساسية الداخلية للجهاز. وأخيرا، أنتجت جميع عينات المياه نتائج إشعاعية منخفضة جدا، مما أدى إلى الاستنتاج إلى أن استخدام الصنبور والمياه المعدنية في المناطق المحللة من العراق يمثل قلقا إشعاعيا غير مهم للحالة الصحية البشرية، حيث أن جميع المعايير الإشعاعية لجميع العينات كانت أقل بكثير من معايير التدخل الدولية الموصى بها.

الكلمات المفتاحية :تحليل إشعاعي، معدل الجرعة، تلوث السطح، ماء الصنبور، المياه المعدنية، RadEye B20.