Measurement of radiological baseline data of the hazard radiation in bottled drinking water samples in Basra/Iraq

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Abstract

An investigation was carried out on several radiological hazard indices in twenty three bottled drinking water samples that were collected from various locations in Basrah/Iraq. The specific activity of 238U, 232Th, 40K and 137Cs isotopes was measured using the surveillance and measurement (SAM) device, model 940-2G. The specific activity values of U-238, Th-232, K-40 and Cs-137 ranged as (0.029±0.001-3.017±0.003) Bq/l, (0.025±0.002-2.326±0.001) Bq/l, (4.706±0.002-161.560±0.001) Bq/l and (0.040±0.003-0.953±0.001) Bq/l, respectively. The calculation of many risk indices has been carried out for all drinking water samples. All results have agreed with those reported in published studies and all these obtained findings have been recognized to be below the worldwide limit values. Therefore, there is no significant radiological risk in drinking bottled water brands in Basrah governorate, Iraq.

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1. Introduction

The assessment of naturally occurring radioactive materials (NORM) in drinking water provides significant information about the quality of drinking water. This type of health studies permits the calculation of population exposure to radioactivity by the drinking of healthy water [1-6]. Uranium decay chain, thorium decay chain and potassium are classified as naturally occurring radioactive materials (NORM). These isotopes can be easily detected by gamma ray spectroscopy because of their abundant in the natural atmosphere [7, 8]. The world population is subjected to the numerous types of radiation sources including artificial radiation (15%) and natural radiation (85%) in which foodstuffs and drinks contain 11%. This may give a chance to the contamination of radioactive materials [9]. Drinking water can be affected by man-made radiation caesium-137 (^{137}Cs) which made through nuclear accidents and processes is an example of anthropogenic radionuclides [10]. The average of doses to many of organs of the human body also represent a significant way for long-term health conditions [11]. Most of people are subjected to these sorts of radiation sources every day and in anywhere. Water is one of the basic constituents of the human diet [12]. Over recent years, bottled drinking water has widely consumed around the world [2]. Thus, a great deal of research has been carried out about the radioactivity of bottled drinking water in different countries [1-7, 13, 14]. For a systematic methodology, this research concentrated on bottled drinking water that is widely consumed by various age groups in Basrah, Iraq. It is very necessary of Iraqi government to control local bottled drinking water to check that are uncontaminated with isotopes. This study is critical in determining the radiation hazard on human and essential in creating procedures and rules involving to radiation protection. It is critical for calculating the radiation levels that affect Iraqi population. That is because the excessive exposure of the radiation may cause major health problems such as carcinogenesis [9]. That is why this study is significant to be done. The measurement of radioactivity in bottled drinking water is very important for monitoring radiation hazards on human health [2, 15]. This scientific research is aimed to create radiological baseline data of the hazard radiation in bottled drinking water samples in Basrah/Iraq. This aim to be achieved the levels of radioactivity and radiation risk indices of consumed bottled drinking water types in Basra, Iraq are essential to be calculated and investigated.

2. Materials and Methods

Twenty three brands of bottled drinking water were selected and then all samples were bought from local markets in Basrah governorate as showing in Table 1. . The sample collection was made between April and May of 2019. This study was conducted over a four-month period (from April 2019 to July 2019).

Table 1: Significant information about Iraqi water samples (500ml)

Sample code	Sample commercial name	Sample origin City
W1	Ayoon	Baghdad
W2	Durat Al-khaleej	Basrah
W3	Ala	Baghdad
W4	Alam	Basrah
W5	Al-bakera	Babylon
W6	Aljnaaen	Basrah
W7	Miah Aljanoob	Basrah
W8	Alkafal	Karbala
W9	Alkotheer	Basrah
W10	Nabee-Alkwthar	Baghdad
W11	Alrawase	Basrah
W12	Al-Ssad	Baghdad
W13	Aquasil	Basrah
W14	Barada	Basrah
W15	Hani	Baghdad
W16	Life	Sulaymaniyah
W17	Mowj	Muthanna
W18	Nawar	Basrah
W19	Salsal	Basrah
W20	Al-rawia	Baghdad
W21	Veneza	Baghdad
W22	Wadi Mina	Basrah
W23	Der Alynabee	Basrah

Each 500 ml of water sample was weighed and put in 500 ml polyethylene plastic Marinelli beakers (pail) and properly stored. The storage period of labeled samples was for 30 days to reach equilibrium between parents and their daughters [16]. The measurements of all samples were carried out by SAM940-2G device operating with NaI(Tl) gamma-ray detector. Surveillance and Measurement (SAM940-2G) operating with BNC 2″x2″ gamma-ray NaI(Tl) detector has 256 channels, voltage operation of 600 Volts, coarse gain=1 and fine gain=1.1386. The energy calibration, resolution calibration and efficiency calibration of a BNC 2"x2" NaI (Tl) detector were determined experimentally for (32.90, 661.7, 31.63, 80.90, 356.01, 1173.20 and 1332.50) keV. The calculation of the activity level and presence of ^{238}U and ^{232}Th in all samples was derived by arithmetical average of activities took from the peaks of their daughters in the water spectrum. ^{238}U derived from ^{214}Bi (609.32 keV) and ^{214}Pb (295.21 and 351.92 keV). ^{232}Th derived from ^{212}Pb, ^{208}Tl and ^{228}AC at energies of 238.63, 583.19 and 911.16 keV respectively. The activity values of ^{40}K in all samples were determined from the single peak of potassium at 1461 keV. The present work has determined the activity values and existence of caesium-137 (^{137}Cs) in all samples at energy of 661.61 keV. The measurement time for each sample was 1800 seconds.

The specific activity (A_s) was measured applying the following expression [17-19]:

$$A_s\left(\frac{Bq}{l}\right)=\frac{N}{\varepsilon_f \times P_\gamma \times m \times t_s} \qquad \text{..... (1)}$$

where, N = count per second (cps), ε_f = the efficiency at the peak energy, t_s = the live time of the spectrum of sample (1800 seconds), m = volume (0.5 l) and P_γ = the probability of gamma-ray emission.

The rate of absorbed dose which is measured by (nGy/h) is obtained using the indicated relation [20]:

$$D\left(\frac{nGy}{h}\right)=0.461A_U+0.623A_{Th}+0.0414A_k \qquad \text{..... (2)}$$

where, A_U is the specific activity of ^{238}U, A_{Th} is the specific activity of ^{232}Th, and A_K is the specific activity of ^{40}K.

^{238}U (^{226}Ra), ^{232}Th, and ^{40}K are used to obtain the annual effective dose equivalent as showing in the following equations [20]:

$$AEDE_{outdoor}\left(\frac{msv}{y}\right)=D\times 8760\times 0.7\times 0.2\times 10^{-6} \qquad \text{..... (3)}$$

$$AEDE_{indoor}\left(\frac{msv}{y}\right)=D\times 8760\times 0.7\times 0.8\times 10^{-6} \qquad \text{..... (4)}$$

where, D is the rate of absorbed dose measured in *nGy/h*. The number of 0.2 refers to outdoor occupancy factor, 0.8 is indoor occupancy factor, 0.7 Sv/Gy is conversion factor. The cancer risk due to gamma radiation effects which is called Excess Lifetime Cancer Risk can be considered as following [19, 21]:

$$ELCR = AEDE \times DL \times RF \quad ..... (5)$$

where, *AEDE*, *DL* and *RF* are the equivalent of annual effective dose, the average of human age (70 years) and the factor of risk respectively. The value of risk factor in the public is 0.05 per Sievert as recommended by ICRP for stochastic effects [10, 21].

The activity levels of ^{238}U, ^{232}Th and ^{40}K are inhomogeneous distributed in the water samples. Hence, all samples would be examined by radium equivalent activity. The Ra_{eq} which measured in Bq l^{-1} can be measured by the following formula [17, 19, 22]:

$$Ra_{eq}(\frac{Bq}{l}) = A_U + 1.43A_{Th} + 0.077A_k \quad ..... (6)$$

The internal (H_{in}) and external hazard (H_{ex}) indices to gamma ray radiation in water samples were measured applying the following equations [17, 19, 22]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad ..... (7)$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad ..... (8)$$

The radiological risk of gamma index (I_γ) is calculated through the following formula [17, 19]:

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad ..... (9)$$

Alpha index was measured by applying the following relation [17, 19] :

$$I_\alpha = \frac{A_{Ra}}{200} \quad ..... (10)$$

where A_{Ra} are the specific activity of ^{226}Ra supposed in equilibrium with the specific activity of ^{238}U.

3. Results and Discussion

The specific activity of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in different types of water samples has been measured using equation 1 and their results are reported in Table 2. The specific activity of ^{238}U was ranged from (0.029±0.001) Bq l^{-1} to (3.017±0.003) Bq l^{-1}. As for ^{232}Th, was ranged from (0.025±0.002) Bq l^{-1} to (2.326±0.001) Bq l^{-1}. For ^{40}K was ranged from (4.706±0.002) Bq l^{-1} to (161.560±0.001) Bq l^{-1}. As for ^{137}Cs, it was ranged from (0.040±0.003) Bq l^{-1} to (0.953±0.001) Bq l^{-1}. The average specific activity of ^{40}K is higher than those of ^{238}U, ^{232}Th and ^{137}Cs. The world average limit specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are 33 Bq l^{-1}, 45 Bq l^{-1}, 412 Bq l^{-1} and 101 Bq l^{-1}, respectively [23, 24]. The gamma absorbed dose rates which calculated by using equation 2 for all samples in this study were ranged between 0.098 nGy/h and 7.610 nGy/h as shown in Table 3. The outcomes obtained for absorbed dose rates appeared lower than the international limit value of 58 nGy/h reported in UNSCEAR 2000 [20]. Taking into account a 20% outdoor and 80% indoor occupancy factors, the $AEDE_{outdoor}$ and $AEDE_{indoor}$ values were measured for all water samples in this work as shown in Table 3. The mathematical calculations of these quantities were achieved using equations 3 and 4. The lowest value of both $AEDE_{outdoor}$ and $AEDE_{indoor}$ was 0.000 mSv/y whereas the highest values of $AEDE_{outdoor}$ and $AEDE_{indoor}$ were 0.009 mSv/y and 0.037 mSv/y, respectively as shown in Table 3. The achieved results demonstrate that the AEDE in all samples do not appear higher than the world average annual effective dose equivalent. The estimated world average $AEDE_{outdoor}$ and $AEDE_{indoor}$ are 0.07 mSv/y and 0.34 mSv/y respectively, as recommended by UNSCEAR 2000 [20]. The outdoor and indoor excess lifetime cancer risk (ELCR) values were measured for all samples as shown in Table 3. The mathematical calculations of these quantities were done using equation 5. The consequences obtained show that the ELCR in all water samples appeared below the world average excess lifetime cancer risk. The estimated world average $ELCR_{outdoor}$ of 0.29×10^{-3} and $ELCR_{indoor}$ of 1.4×10^{-3} reported in UNSCEAR 2000 [10, 25]. The radium equivalent activity, internal and external radiation hazard indices, the gamma index and alpha index were calculated by applying the equations 6, 7, 8, 9 and 10 respectively. There is a variation in the values of these radiation hazard indices in all samples as reported in Table 4, Fig.1 and Fig. **2**. The results of all risk indices are not higher than world limit values.

Table 2: Specific activity results of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in water samples

Sample code	**Specific activity (A_s) in (Bq l^{-1}) (± Uncertainty)**			
	^{238}U	**^{232}Th**	**^{40}K**	**^{137}Cs**
W1	ND	0.489±0.004	ND	ND
W2	ND	2.326±0.001	34.508±0.002	ND
W3	0.211±0.001	0.914±0.002	ND	ND
W4	1.084±0.001	1.593±0.002	4.706±0.002	ND
W5	0.211±0.001	0.914±0.002	ND	ND
W6	1.242±0.008	0.790±0.003	10.196±0.002	ND
W7	0.404±0.001	0.025±0.002	ND	ND
W8	0.052±0.005	1.441±0.003	161.560±0.001	ND
W9	0.211±0.002	0.914±0.002	ND	ND
W10	ND	0.157±0.005	ND	0.179±0.003
W11	ND	0.157±0.005	ND	0.179±0.003
W12	0.948±0.001	1.921±0.002	71.369±0.001	0.953±0.001
W13	0.424±0.009	0.727±0.002	9.411±0.002	0.258±0.003
W14	0.029±0.001	0.482±0.002	30.587±0.002	0.357±0.002
W15	0.200±0.001	0.402±0.001	ND	ND
W16	0.701±0.001	1.301±0.003	43.919±0.002	ND
W17	0.029±0.004	0.482±0.001	30.587±0.002	0.357±0.003
W18	3.017±0.003	1.307±0.003	36.861±0.002	ND
W19	0.245±0.002	0.941±0.002	21.960±0.002	0.119±0.004
W20	0.029±0.007	0.482±0.002	30.587±0.002	0.357±0.003
W21	1.150±0.004	0.672±0.001	79.996±0.007	0.040±0.003
W22	ND	0.620±0.002	ND	ND
W23	0.178±0.003	1.118±0.004	6.274±0.002	0.179±0.003
Minimum	0.029±0.001	0.025±0.002	4.706±0.002	0.040±0.003
Maximum	3.017±0.003	2.326±0.001	161.560±0.001	0.953±0.001

*ND: Not detected

Table 3: The results of gamma absorbed dose rates (D), annual effective dose equivalent values (AEDE) and excess lifetime cancer risk values (ELCR) in all samples

Sample code	D (nGy/h)	$AEDE_{Outdoor}$ (mSv/y)	$AEDE_{Indoor}$ (mSv/y)	$ELCR_{Outdoor}$	$ELCR_{Indoor}$
W1	0.305	0.000	0.001	0.001	0.005
W2	2.878	0.004	0.014	0.012	0.049
W3	0.667	0.001	0.003	0.003	0.011
W4	1.687	0.002	0.008	0.007	0.029
W5	0.667	0.001	0.003	0.003	0.011
W6	1.487	0.002	0.007	0.006	0.026
W7	0.202	0.000	0.001	0.001	0.003
W8	7.610	0.009	0.037	0.033	0.131
W9	0.667	0.001	0.003	0.003	0.011
W10	0.098	0.000	0.000	0.000	0.002
W11	0.098	0.000	0.000	0.000	0.002
W12	4.589	0.006	0.023	0.020	0.079
W13	1.038	0.001	0.005	0.004	0.018
W14	1.580	0.002	0.008	0.007	0.027
W15	0.342	0.000	0.002	0.001	0.006
W16	2.952	0.004	0.014	0.013	0.051
W17	1.580	0.002	0.008	0.007	0.027
W18	3.731	0.005	0.018	0.016	0.064
W19	1.608	0.002	0.008	0.007	0.028
W20	1.580	0.002	0.008	0.007	0.027
W21	4.261	0.005	0.021	0.018	0.073
W22	0.386	0.000	0.002	0.002	0.007
W23	1.038	0.001	0.005	0.004	0.018
Minimum	0.098	0.000	0.000	0.000	0.002
Maximum	7.610	0.009	0.037	0.033	0.131

Table 4: The results of radium equivalent activity, radiation hazard (internal, external, gamma and alpha) indices in all samples

Sample code	Ra_{eq} (Bq l^{-1})	H_{in}	H_{ex}	I_{γ}	I_{α}
W1	0.700	0.002	0.002	0.002	0.000
W2	5.984	0.016	0.016	0.023	0.000
W3	1.518	0.005	0.004	0.005	0.001
W4	3.723	0.013	0.010	0.013	0.005
W5	1.518	0.005	0.004	0.005	0.001
W6	3.157	0.012	0.009	0.011	0.006
W7	0.439	0.002	0.001	0.001	0.002
W8	14.553	0.039	0.039	0.061	0.000
W9	1.518	0.005	0.004	0.005	0.001
W10	0.225	0.001	0.001	0.001	0.000
W11	0.225	0.001	0.001	0.001	0.000
W12	9.191	0.027	0.025	0.037	0.005
W13	2.188	0.007	0.006	0.008	0.002
W14	3.074	0.008	0.008	0.013	0.000
W15	0.774	0.003	0.002	0.003	0.001
W16	5.944	0.018	0.016	0.023	0.004
W17	3.074	0.008	0.008	0.013	0.000
W18	7.724	0.029	0.021	0.029	0.015
W19	3.281	0.010	0.009	0.013	0.001
W20	3.074	0.008	0.008	0.013	0.000
W21	8.271	0.025	0.022	0.034	0.006
W22	0.887	0.002	0.002	0.003	0.000
W23	2.260	0.007	0.006	0.008	0.001
Minimum	**0.225**	**0.001**	**0.001**	**0.001**	**0.000**
Maximum	**14.553**	**0.039**	**0.039**	**0.061**	**0.015**

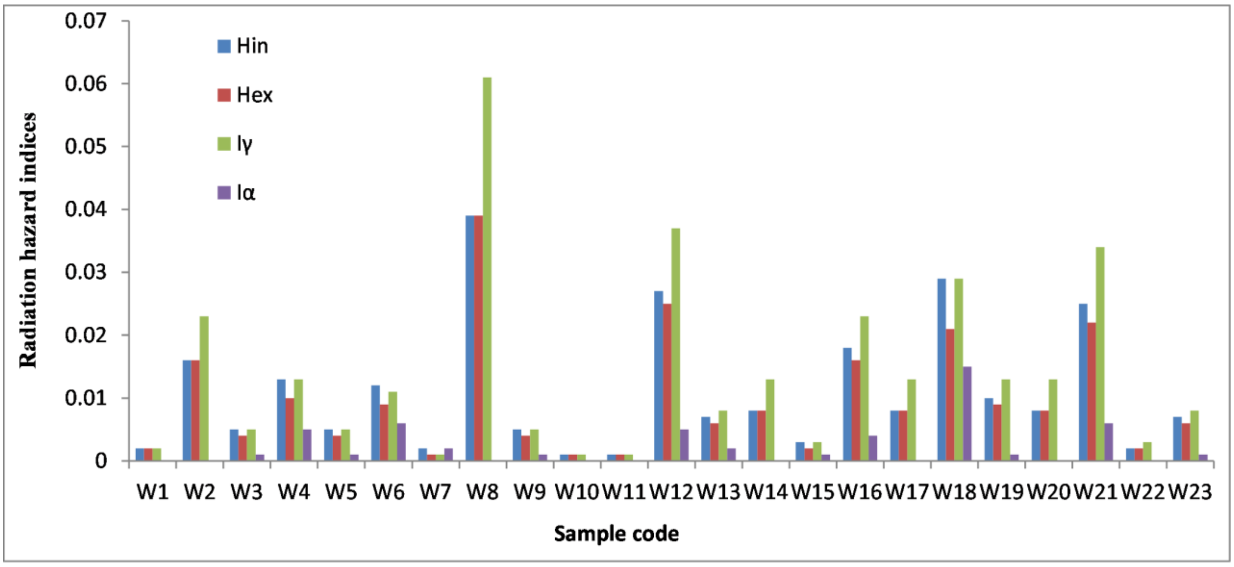

Fig. 1: Radiation hazard (internal, external, gamma and alpha) indices in all samples

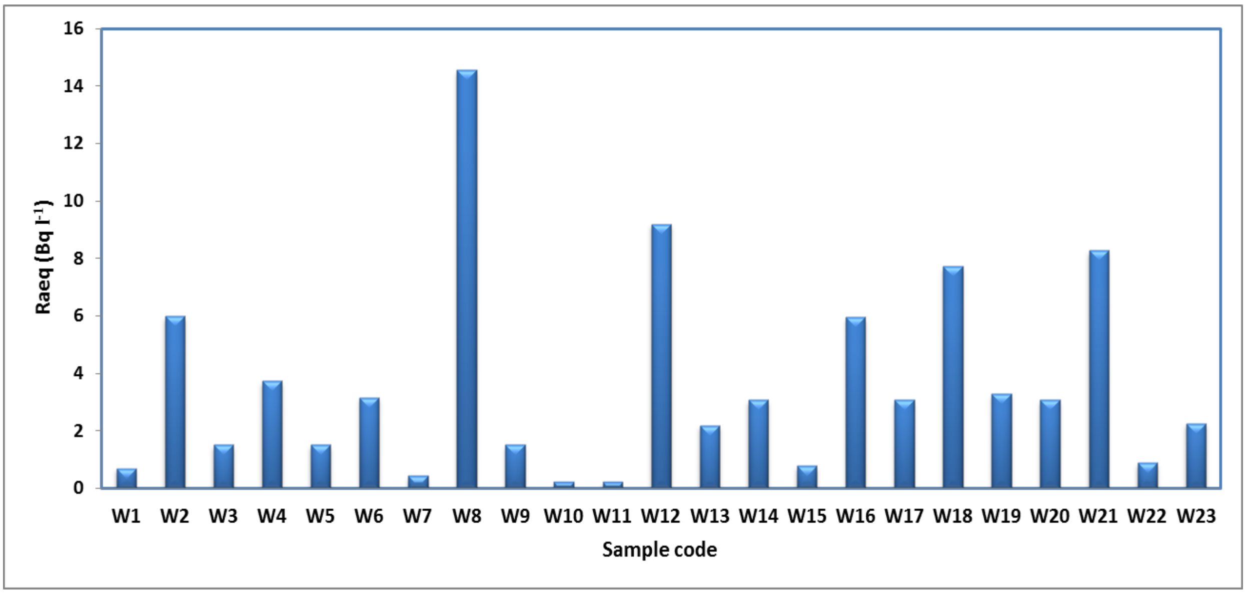

Fig. 2: The radium equivalent activity in all samples

The findings show that the specific activity of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in all water samples appeared lower than the world average specific activity values. The higher average specific activity of ^{40}K compared with the average activity of ^{238}U, ^{232}Th and ^{137}Cs was expected because of its natural presence [26]. The levels of background and the detection limits of technique may conceal minor peaks of ^{238}U, ^{232}Th [27]. Previous studies reported that the detection of ^{238}U and ^{232}Th is not necessary to be found in all food samples [28, 29]. The existence of ^{137}Cs in water samples may because of the Chernobyl accident fallout, the usage of contaminated water bottles [8].

The variability in the unique behaviour of isotopes in the water samples of different Iraqi cities may be due to their geographical and geological conditions.

3. Conclusions

This study investigates the calculation of dose levels and determines the specific activity of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in all samples of drinking water that were collected from various locations in Basrah / Iraq. Therefore, it can be concluded that there is no significant radiological risk in drinking bottled water brands in Basrah governorate, Iraq.

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قياس النشاط الاشعاعي للمياه المعبأة بالقناني في البصرة/ العراق

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2قسم العلوم الاساسية، كلية طب الاسنان، جامعة البصرة، البصرة، العراق

المستخلص

الهدف من هذه الدراسة قياس النشاط الاشعاعي في قناني مياة الشرب المستهلكة في البصرة / العراق، وحساب العديد من مؤشرات الخطر الإشعاعي. جمعت 23 عيّنة من من قناني مياة الشرب من الأسواق المحلية لمختلف المناطق في محافظة البصرة. حدد النشاط الإشعاعي (بيكريل / لتر) لنظائراليورانيوم 238 و الثوريوم 232 والبوتاسيوم 40 والسيزيوم 137 في عيّنات مياه الشرب المعبأة بواسطة جهاز قياس ومراقبة الاشعاع (SAM940) بتشغيل برامج حاسوبية خاصة يتم من خلالها التحكم بالجهاز عن بُعد وإجراء جميع التحليلات للأطياف. النشاط الإشعاعي (بيكريل / لتر) لنظائراليورانيوم 238 و الثوريوم 232 والبوتاسيوم 40 والسيزيوم 137 هي (0.029±0.001-3.017±0.003) بيكريل / لتر، (0.025±0.002-2.326±0.001) بيكريل / لتر، (4.706±0.002-161.560±0.001) بيكريل/ لتر و (0.040±0.003-0.953±0.001) بيكريل / لتر، على التوالي. حسبت العديد من مؤشرات الخطر الإشعاعي لجميع العيّنات في هذه الدراسة. تمت مقارنة نتائج الدراسة الحالية بالدراسات السابقة وبقيم الحد الأقصى في جميع أنحاء العالم. وقد اتفقت جميع النتائج مع تلك الموصوفة في الدراسات السابقة ، وتبين أنَّ جميع النتائج ضمن الحدود المسموح بها عالميا. ومنَ ثمَّ ، فإنَّ الأنواع المختارة من المواد الغذائية هي آمنة للاستهلاك في محافظة البصرة. يمكن استخدام نتائج هذه الدراسة في توفير قاعدة بيانات أساسية لمعدلات الإشعاع الطبيعي والصناعي في المواد الغذائية الأساسية المستهلكة في البصرة / العراق.

كلمات مفتاحية: النشاط الإشعاعي، جهاز قياس ومراقبة الاشعاع (SAM940)، قناني مياة الشرب، محافظة البصرة