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Evaluation of Uranium Concentration and Calculated Doses of Radiation Resulting From the Tap and Bottled Drinking Water in Babylon - middle Iraq

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Abstract

In this study, uranium concentrations were evaluated and the annual effective dose was calculated from the consumption of bottled water and tap water used for drinking in Babylon, middle Iraq. Uranium isotopes (^{238}U, ^{234}U, ^{235}U) were determined for all samples collected using the phosphorylation analyzer technique represented device (KPA). Forty-four samples were collected to cover almost all districts and regions of Babylon. Thirty tap water samples were collected from residential neighborhoods, with 14 samples from local brand bottled water. The results show that the uranium concentrations in the tap water samples ranged from 1.66 $\mu g.L^{-1}$ to 2.64 $\mu g.L^{-1}$, with an average of 2.12 $\mu g.L^{-1}$, and the bottled water samples varied from 1.06 $\mu g.L^{-1}$ to 1.82 $\mu g.L^{-1}$, with an average 1.47 $\mu g.L^{-1}$. This means that the uranium contents in tap and bottled water samples are less than 15 $\mu g.L^{-1}$ and 30 $\mu g.L^{-1}$, which are safe values of the WHO, and the EPA respectively. The annual effective dose values of ^{238}U, ^{234}U, and ^{235}U for adult consumption of tap water range between 0.67, 0.0.33, 0.74 $\mu Sv.y^{-1}$ to 1.07, 0.052, 1.18 $\mu Sv.y^{-1}$ with averages of 0.86, 0.042, 0.95 $\mu Sv.y^{-1}$, respectively. Their values in bottled water ranged from 0.43, 0.020, 0.47 $\mu Sv.y^{-1}$ to 0.73, 0.035, 0.81 $\mu Sv.y^{-1}$, with an average of 0.59, 0.029, 0.65 $\mu Sv.y^{-1}$, respectively. The value of the annual effective dose of total uranium isotopes in tap water samples ranged between 1.45 $\mu Sv.y^{-1}$ to 2.30 $\mu Sv.y^{-1}$ with an average of 0.85 $\mu Sv.y^{-1}$, whereas in bottled water varied from 0.92 to 1.58 $\mu Sv.y^{-1}$ with an average of 1.28 $\mu Sv.y^{-1}$.

Keywords: Uranium concentrations; Uranium isotopes; KPA; Tap water; Babylon.

تقييم تركيز اليورانيوم وحساب الجرعات الإشعاعية الناتجة من مياه الحنفية ومياه الشرب المعبأة في بابل – وسط العراق

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الخلاصة

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في هذه الدراسة تم تقييم تراكيز اليورانيوم وحساب الجرعة الفعالة السنوية من استهلاك المياه المعبأة ومياه الصنبور المستخدمة للشرب في محافظة بابل وسط العراق. تم تحديد نظائر اليورانيوم (^{238}U و ^{234}U و^{235}U) لجميع العينات التي تم جمعها باستخدام تقنية محلل الفسفرة ممثلة بجهاز(KPA) . تم جمع 44 عينة من جميع أقضية ومناطق بابل تقريباً ,30 عينة من مياه الصنبور من الأحياء السكنية و14 عينة من المياه المعبأة في قناني من الأسواق المحلية. بينت النتائج ان تراكيز اليورانيوم في عينات مياه الصنبور تراوحت من 1.66 ميكروغرام/ لتر إلى 2.64 ميكروغرام/ لتر، وكان المتوسط 2.12 ميكروغرام/ لتر. تراوحت تراكيز اليورانيوم في عينات المياه المعبأة من 1.06 ميكروغرام / لتر إلى 1.82 ميكروغرام / لتر ، وكان المتوسط 1.47 ميكروغرام / لتر. وجد من خلال المتوسط لجميع العينات تركيز اليورانيوم في ماء الصنبور والمياه المعبأة أقل من (15 ميكروغرام / لتر ، 30 ميكروغرام / لتر) وهي القيم الآمنة لمنظمة الصحة العالمية ووكالة حماية البيئة على التوالي. قيم الجرعة الفعالة السنوية لنظائر اليورانيوم (^{238}U، ^{234}U،^{235}U) لاستهلاك البالغين من ماء الصنبور والمياه المعبأة والتي تراوحت بين 0.67 ، 0.0.33 ، 0.74 ميكرو سيفرت / سنة إلى 1.07 ، 0.052 ، 1.18 ميكرو سيفرت / سنة ، ومتوسط 0.86 ، 0.042 ، 0.95 ميكرو سيفرت / سنة على التوالي لمياه الصنبور. تراوحت قيمه في المياه المعبأة بين 0.43 ، 0.020 ، 0.47 ميكرو سيفرت / سنة إلى 0.73 ، 0.035 ، 0.81 ميكرو سيفرت / سنة ، ومتوسط 0.59 ، 0.029 ، 0.65 ميكرو سيفرت / سنة على التوالي. تراوحت قيمة الجرعة الفعالة السنوية من إجمالي نظائر اليورانيوم في جميع عينات مياه الصنبور بين (1.45 ميكرو سيفرت / سنة إلى 2.30 ميكرو سيفرت / سنة) ومتوسط (0.85 ميكرو سيفرت / سنة)، بنما تراوحت في عينات المياه المعبأة من 0.92 إلى 1.58 ميكرو سيفرت/سنة، وبمتوسط 1.28 ميكرو سيفرت / سنة.

Introduction

The water demand is increasing due to population growth and increasing urbanization. Water supply is also affected by human activities represented by the expansion of cities, agricultural and industrial activity, wastes, and natural conditions such as the amount of precipitation [1]. Water quality control is necessary for public health because the deterioration of water quality affects consumers [2].

In a previous study [3;4], radon and radium concentrations in groundwater in the Hashimiya area were done. They estimated the radiation dose and risk and concluded that elevated radon concentrations in groundwater were found to be higher than the new WHO recommended level (0.1 mSv/y) for drinking water. Because of the high radon and radium gas values in the Hashemite region, The Environmental Department in Babylon recommended conducting this study due to the long-term hazards of the radioactive materials.

People are subjected to a dose of radioactivity when they ingest uranium concentrations solute in water, where uranium is one of the radioactive elements that occur naturally and is available in the crust of the earth in three isotopes (^{238}U, ^{235}U, and ^{234}U) [5]. Uranium is in detectable concentrations in most natural waters and is water-soluble [6;7]. It is toxic chemically and radiologically depending on concentration, exposure period, solubility, chemical nature, and residence time in the body [8]. Uranium is classified as a contaminant, particularly in drinking water, so the drinking water systems must undergo extensive monitoring for radioactive contamination to ensure the water quality. Estimating uranium in water may also be significant for hydrochemical studies, health risk assessments, and mitigation operations. The drinking water containing high levels of uranium causes adverse health effects and accumulates in vital human organs and exerts progressively growing toxic actions [9]. The radioactivity of uranium is important in estimating the annual effective dose for people, as it may be available in all regions of the world.

Non-degradable uranium can cause adverse health effects through prolonged drinking of water that contains high levels of uranium, which causes increasingly harmful activities to grow in the human organs in which it accumulates [10]. According to its chemical toxicity, the water supply for people should be less than the maximum levels of contamination (MCL) recommended by many national and international organizations for total uranium concentrations such as15 μg.L^{-1}, 30 μg.L^{-1} [11; 12]. According to its radiological effect, the radioactivity should be less than 1Bq/kg and 0.04 Bq/kg for ^{238}U and ^{235}U respectively. The WHO recommended that radioactivity of ^{238}U, ^{235}U and ^{234}U in drinking water should not exceed 10, 1 and 1 Bq.kg^{-1} respectively. These radioactivity values may cause an annual effective dose (0.1 mSv.y^{-1}) for each radionuclide.

The objective of this study is to measure the concentration of uranium isotopes (^{238}U, ^{234}U, ^{235}U) by using the KPA technique in bottled and tap waters used for drinking in Babylon governorate and estimate the annual effective doses caused by consuming these waters [13].

The study area

The study was conducted in the province of Babylon, which is located in the center of Iraq and determined by coordinates 44°00 '- 45°08' E, 32°70 '- 31°90' N. People in the study area depend on the Euphrates River, and its branches for drinking water and other uses through several stations refine the river's water and supply to consumers. The Hilla River is the only surface water source in the study area that enters the area from the western side and leaves it from the southeast side. At the Al Hindiya embankment, the Euphrates River branches to the Hilla and Al-Hindiya Rivers; and passes through Al-Kifl. The Hilla River is one of the largest streams that take water in front of the Hindiya dam. Some residents usually use local brands of bottled water. The base map of the study area displays the water sampling sites (Figure 1). The potential sources of uranium in the study area are either the result of the interaction of soil and water or external pollution [3;4].

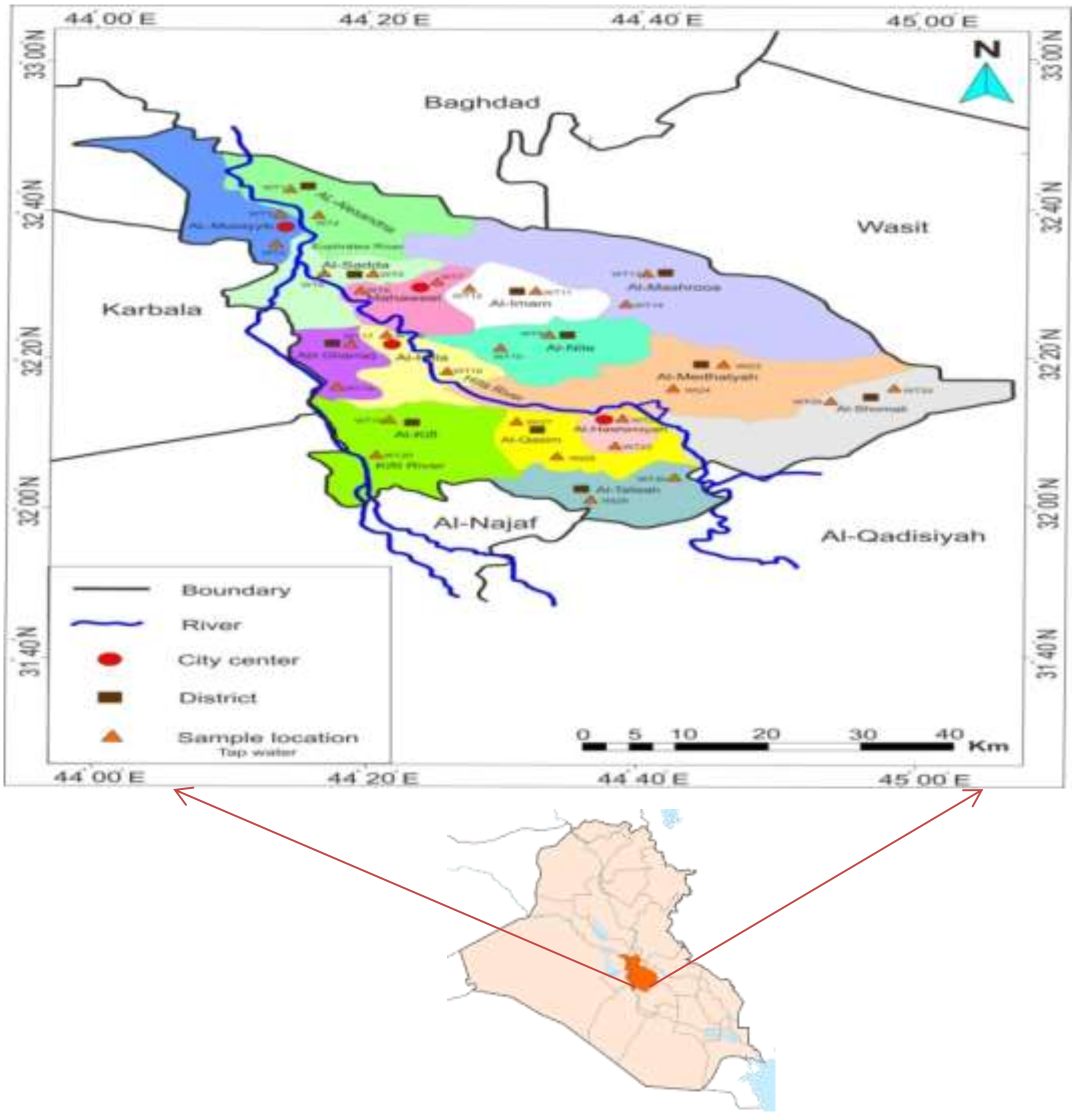

Figure 1: Location of study area showing locations samples oftap water

Material and method

Sample Collection

Samples of tap and bottled water were collected from several locations covering all regions of the governorate (Al Hillah, Musayyib, Al Mahaweel, and Al Hashimiyah). A total number of 44 samples were divided into two parts. The first part (30 tap water samples) was collected from residential neighborhoods, and the second part (14 bottled water samples) was collected from local markets. The uranium concentrations in these samples were measured using Kinetic phosphorescence analysis (KPA) at the laboratories of the Radiation Protection Center, Iraqi Ministry of Environment. The physical properties, main ion concentrations, pH, Total dissolved solids (TDS), and Total Hardness (TH) were measured to find the relationship between uranium concentrations and these parameters. The sampling was done from December 2020 to September. 2021.

The device of the KPA

Figure 2 displays the device KPA, Chemchek Instruments inc., USA [14]. It is used to measure uranium concentrations in the different sample types. The KPA device has modern technology in the world by using laser technology and a kinetic phosphorus analysis system. The accuracy gives an advantage and importance as it can detect uranium concentrations with an accuracy of up to 0.01 µg.L-1 [15]. The correlation coefficient R^2 of the device has been calibrated by the manufacturer, the device's accuracy was duplicate tested by repeated measurement of the samples, and it was noted that the difference in the results is not more than 2.5% on a clear linear correlation coefficient [16].

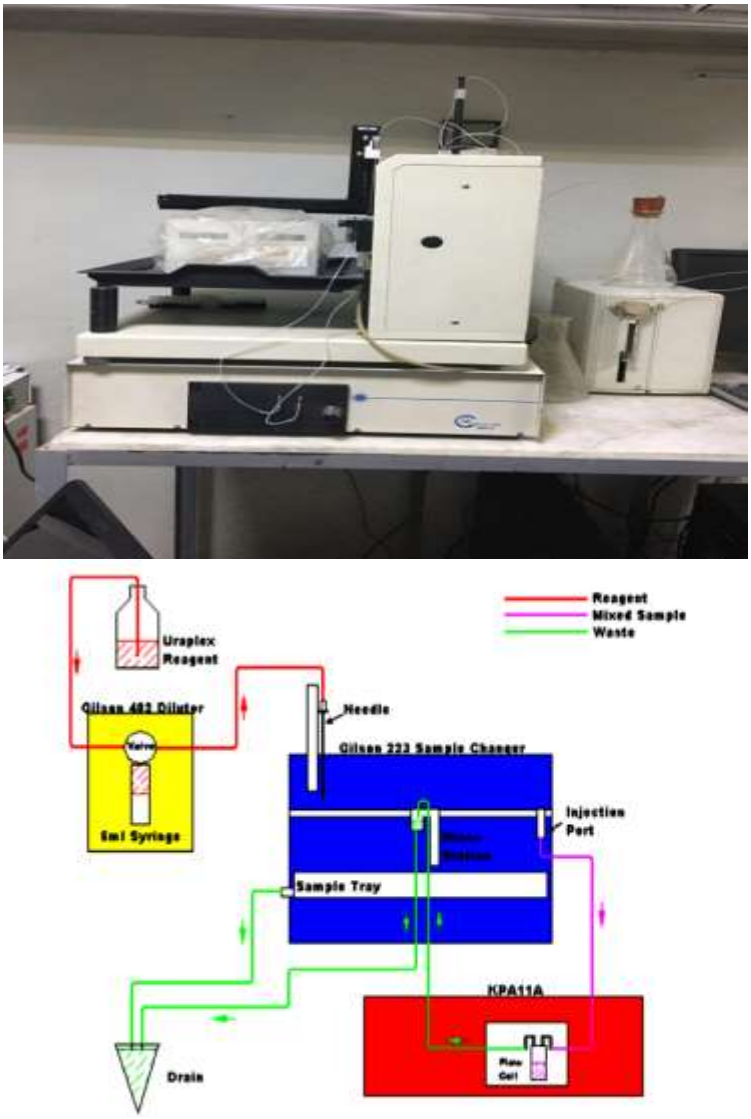

Figure 2: Diagram of KPA, showing tubing of the kinetic phosphorescence analyzer [17].

Water Sample Preparation Steps for KPA

The procedure of ASTM [18] was used to measure a drinking water sample:

1- Tube 5 ml of the sample into a pre-treated glass vial.

2- Add 1 mL of concentrated HNO3 and two or three drops of 30% hydrogen peroxide.

3- Place the bottle on a hot plate and heat it to dry. Avoid scattering the sample.

4- Remove the vial from the hot plate and add concentrated 1 ml HNO3 and two or three drops of 30% hydrogen peroxide and heat to dryness. Repeat this process as necessary until a white or transparent residue remains.

5- Add 1 ml of 4M HNO3 and warm gently, if needed, to dissolve the residue. Then add 4 ml of water. Vortex to mix well.

6- Use KPA-11for analyze the solution.

Uranium concentration (UC) (mg. L^{-1}) in the sample is calculated by the KPA, using equation 1 [19; 20].

$$UC = Ut\ (Wa + Fb) \qquad \ldots.\ 1$$

where Ut is the weight (mg) of the total uranium, Wa is the aliquant weight in grams, and Fb is the dilution factor (gram sample/gram solution). The KPA device is controlled by software operating under windows to calculate uranium concentration [14] automatically.
The activity in Becquerel.L^{-1} (Bq L^{-1}) of the three isotopes ^{238}U, ^{235}U, and ^{234}U can be calculated by knowing their mass fraction and specific activity, as shown in Table 1 using equation 2.

$$A(Bq.L^{-1}) = UC(mg.L^{-1}) \times IAM(\%) \times SPA(Bq.mg\text{-}1) \qquad \ldots.2$$

where A(Bq.L^{-1}) is the specific activity, I.A.M(%) is the isotopic abundance by mass fraction, and S.P.A is the specific activity [21;22].

Table 1: Radioactive characterize of uranium isotopes [21,22]

Isotope	Specific activity for Uranium (Bq.mg^{-1})	Mass fraction (%)	half-life (year)
^{238}U	12.44	99.2745	$4.47*10^{9}$
^{235}U	80	0.72	$7.038*10^{8}$
^{234}U	230,700	0.0055	245.500

Annual Effective Dose AED (Sv.)

The annual effective dose measured in Sievert (Sv) can be evaluated for the public by calculating the ^{238}U, ^{235}U, and ^{234}U in the ingested water and using equation 3.

AED (Sv) = Radioactivity Concentration in water (Bq.L^{-1}) × Annual Consumption of water (L) × Radioactivity Dose Conversion Factor (Sv.Bq^{-1}) ….3

Results and Discussions

In this work, the concentrations of uranium and its isotopes, the daily consumption, and the effective uranium annual dose were assessed in tap and bottled water (Tables 2&3) and Tables (4&5) respectively. The uranium content in the tap water ranged from 1.66 μg.L^{-1} in the Al-Mashrooa sample (WT13) to 2.64 μg.L^{-1} in the Shomali sample (AWT26), with an average of 2.12 μg.L^{-1}. The uranium concentrations in the bottled water ranged from 1.06 μg.L^{-1} to 1.82 μg.L^{-1}, with an average of 1.47 μg.L^{-1}. The average of uranium in all tap water samples was less than 15μg.L^{-1} meaning a safe level based on the WHO [22]. The average consumption is obtained from the daily intake of tap and bottled samples for the residents of Babylon through the standard rate of international consumption, which is 1.4 L.d^{-1} [23], while a value of 2 L.d^{-1} according to the ICRP[22]. The higher consumption value for adults of 2 L.d^{-1} was taken in the current study as a worst-case for risk assessment [24]. The uranium isotope (^{238}U, ^{235}U, and ^{234}U) activities in the tap water in Babylon ranged from 20.50, 0.95, and 20.67 mBq. L^{-1} to 32.60, 1.52, and 32.88 mBq. L^{-1} with an average of 26.21 to 26.44 mBq. L^{-1}) respectively. The isotope activity values in the bottled water ranged from 13.09, 0.61, and 13.20 mBq. L^{-1} to 22.47, 1.04, and 22.67 mBq. L^{-1} respectively.

The annual effective doses due to consumption of water; they contain isotopes (^{238}U, ^{235}U, ^{234}U) for adult in the districts and regions of Babylon are presented in Tables 2 and 3. These doses for tap water ranged between 0.67, 0.0.33, 0.74 μSv.y^{-1} to 1.07, 0.052,1.18 μSv.y^{-1} with an average of 0.86, 0.042, 0.95 μSv.y^{-1} respectively. In the bottled water, doses ranged between 0.43,0.020,0.47 μSv.y^{-1} to 0.73,0.035,0.81 μSv.y^{-1} with an average of 0.59,0.029,0.65 μSv.y^{-1} respectively.

The value of the annual effective dose of total uranium isotopes in all tap water samples ranged between 1.45 μSv.y^{-1} to 2.30 μSv.y^{-1} with an average of 0.85 μSv.y^{-1}. In contrast, in bottled water, it ranged between 0.92 to 1.58 μSv.y^{-1}, with an average of 1.28 μSv.y^{-1}.
These results showed that it is within the safe limits because it is below the MCL recommended by IAEA, ICRP, EPA, UNSCEAR, and WHO for total uranium concentrations such as 15 μg.L^{-1}, 30 μg.L^{-1}. According to uranium radiological effect does not cause an annual effective dose higher than the AED recommended by WHO, because the radioactivity in the tested tap and bottled water samples is less than 1 Bq.kg^{-1} and 0.04 Bq.kg^{-1} for 238 units and 235 units respectively. The WHO recommended radioactivity ^{238}U, ^{235}U and ^{234}U in the drinking water should not exceed 10, 1,1 Bq.kg^{-1} respectively, and the radioactivity values cause an annual effective dose of 0.1 mSv per radionuclide [11-12].

The physical properties, main ion concentrations, and pH of the bottled and tap water samples were tested. The results showed that the pH value of tap water samples ranged from 7.02 to 7.91, whereas for the bottled water samples ranged between 6.5 and 7.8. The TDS and TH values for tap water samples ranged from 508 and 272.5 to 839 and 417.3 mg/L^{-1}, respectively, while their values in bottled water samples ranged from 28.9 and 5.7 to 91 and 76 mg L^{-1}, respectively. The EC value for tap water samples ranged from 846 to 1281 μs/cm, and bottled water samples ranged from 59 to 182 μs/cm. The concentrations of the ions (Na^+, K^+, Mg^{+2}, Ca^{+2}) for tap water samples ranged from 57.1, 3, 23, and 61.2 to (1.3, 4.41, 4.41, and 8.85 mg/L^{-1}, respectively. The concentration values of the cations above in bottled water samples ranged from 1, 0.1, 0.32, 0.78 to 7.8, 1.3, 19, 26 mg/L^{-1}, respectively. The value of Cl^- and SO_4^{-2} in tap water ranged from 96.5 and 236.7 to 141.2, and 347.8 mg/L^{-1}, respectively, while these values in the bottled water ranged from 7.31 and 14.3 to 16.7 and 62.6 mg/l^{-1} respectively. The concentrations of uranium increase with the increase in the pH value and TDS in most of the collected models (Figures 3, 4, 12, and 13). The relationship reflects clearly the effect of these factors in dissolving uranium and increasing its concentration in water. The higher concentration of uranium in tap water samples than in bottled water samples is due to the use of advanced technology that removes suspended solids from bottled water. The relationship of uranium concentrations with other main ions is not clear, sometimes, it is a direct and sometimes indirect relationship due to the contribution of many factors (Figures 5, 6, 7, 8, 9, and 10).

Table 2: Daily uranium intake of uranium and its isotope concentration in tap water for the districts and regions of Babylon Governorate

districts	sub-district	Symbols of the sample tap water	Ufinal concentration $\mu g.L^{-1}$	Daily uranium intake Id ($\mu g \cdot d^{-1}$)	Active ^{238}U mBq. L^{-1}	Active ^{235}U mBq. L^{-1}	Active ^{234}U mBq. L^{-1}
Al-Musayyib	Al-Alexandria	WT1	2.09±0.01	4.18±0.02	25.81	1.20	**26.03**
		WT2	2.12±0.047	4.24±0.094	26.18	1.22	**26.41**
	Al- Musayyib	WT3	1.97±0.053	3.94±0.106	24.32	1.13	**24.54**
		WT4	1.89±0.053	3.78±0.106	23.34	1.08	**23.54**
	Al- Al-Sadda	WT5	2.26±0.043	4.52±0.086	27.91	1.30	**28.15**
		WT6	2.21±0.057	4.42±0.114	27.29	1.27	**27.53**
Al-Mahaweel	- Al-Mahaweel	WT7	2.05±0.06	4.1±0.12	25.31	1.18	**25.53**
		WT8	2.13±0.096	4.26±0.192	26.30	1.22	**26.53**
	Al-Nile	WT9	1.81±0.072	3.62±0.144	22.35	1.04	**22.54**
		WT10	1.74±0.074	3.48±0.148	21.48	1.00	**21.67**
	Al-Imam	WT11	2.23±0.072	4.46±0.144	27.53	1.28	**27.78**
		WT12	2.19±0.075	4.38±0.15	27.04	1.26	**27.28**
	Al-Mashrooa	WT13	1.66±0.061	3.32±0.122	20.50	0.95	**20.67**
		WT14	1.71±0.064	3.42±0.128	21.11	0.98	**21.30**
Al-Hilla	Al-Hilla	WT15	2.31±0.062	4.62±0.124	28.52	1.33	**28.77**
		WT16	2.29±0.072	4.58±0.144	28.28	1.31	**28.52**
	Abi Gharraq	WT17	2.09±0.06	4.18±0.12	25.81	1.20	**26.03**
		WT18	2.11±0.096	4.22±0.192	26.05	1.21	**26.28**
	Al-Kifl	WT19	2.27±0.072	4.54±0.144	28.03	1.30	**28.27**
		WT20	2.24±0.072	4.48±0.144	27.66	1.29	**27.90**
Al-Hashimiyah	Al-Hashimiyah	WT21	2.33±0.053	4.66±0.106	28.77	1.34	**29.02**
		WT22	2.29±0.047	4.58±0.094	28.28	1.31	**28.52**
	Al-Medhatya	WT23	2.37±0.053	4.74±0.106	29.26	1.36	**29.52**
		WT24	2.41±0.053	4.82±0.106	29.76	1.38	**30.02**
	Al-Shomali	WT25	2.52±0.043	5.04±0.086	31.12	1.45	**31.39**
		WT26	2.64±0.057	5.28±0.114	32.60	1.52	**32.88**
	Al-Qasim	WT27	2.08±0.053	4.16±0.106	25.68	1.19	**25.91**
		WT28	2.11±0.053	4.22±0.106	26.05	1.21	**26.28**
	Al-Talieah	WT29	1.76±0.043	3.52±0.086	21.73	1.01	**21.92**
		WT30	1.81±0.057	3.62±0.114	22.35	1.04	**22.54**

Table 3: The total effective annual dose of uranium isotopes people's consumption in tap water for the districts and regions of Babylon Governorate

districts	sub-district	Symbols of the sample tap water	ET (µSv.y^{-1}) U	ET (µSv.y^{-1}) ^{235}U	ET (µSv.y^{-1}) ^{234}U	Total ET (µSv.y^{-1})
Al-Musayyib	Al-Alexandria	WT1	0.85	0.041	0.93	**1.82**
		WT2	0.86	0.042	0.94	**1.85**
	Al- Musayyib	WT3	0.80	0.039	0.88	**1.72**
		WT4	0.77	0.037	0.84	**1.65**
	Al- Al-Sadda	WT5	0.92	0.045	1.01	**1.97**
		WT6	0.90	0.044	0.98	**1.93**
Al-Mahaweel	- Al-Mahaweel	WT7	0.83	0.041	0.91	**1.79**
		WT8	0.86	0.042	0.95	**1.86**
	Al-Nile	WT9	0.73	0.036	0.81	**1.58**
		WT10	0.71	0.034	0.78	**1.52**
	Al-Imam	WT11	0.90	0.044	0.99	**1.94**
		WT12	0.89	0.043	0.98	**1.91**
	Al-Mashrooa	WT13	0.67	0.033	0.74	**1.45**
		WT14	0.69	0.034	0.76	**1.49**
Al-Hilla	Al-Hilla	WT15	0.94	0.046	1.03	**2.01**
		WT16	0.93	0.045	1.02	**1.99**
	Abi Gharraq	WT17	0.85	0.041	0.93	**1.82**
		WT18	0.86	0.042	0.94	**1.84**
	Al-Kifl	WT19	0.92	0.045	1.01	**1.98**
		WT20	0.91	0.044	1.00	**1.95**
Al-Hashimiyah	Al-Hashimiyah	WT21	0.95	0.046	1.04	**2.03**
		WT22	0.93	0.045	1.02	**1.99**
	Al-Medhatya	WT23	0.96	0.047	1.06	**2.06**
		WT24	0.98	0.048	1.07	**2.10**
	Al-Shomali	WT25	1.02	0.050	1.12	**2.20**
		WT26	1.07	0.052	1.18	**2.30**
	Al-Qasim	WT27	0.84	0.041	0.93	**1.81**
		WT28	0.86	0.042	0.94	**1.84**
	Al-Talieah	WT29	0.71	0.035	0.78	**1.53**
		WT30	0.73	0.036	0.81	**1.58**

Table 4: Daily intake of uranium, and concentrations and its isotopes in bottled water for the districts and regions of Babil Governorate

NO. Sample	locally bottled water	Symbols of the sample of bottle water	U final concentration $\mu g.L^{-1}$	Daily uranium intake Id ($\mu g \cdot d^{-1}$)	Active ^{238}U $mBq.^{L-1}$	Active ^{235}U $mBq.^{L-1}$	Active ^{234}U $mBq.^{L-1}$
1	Aquafina	WB1	1.32±0.08	2.64±0.16	16.30	0.76	**16.44**
2	Afiat	WB2	1.45±0.02	2.9±0.04	17.90	0.83	**18.06**
3	Allueluah	WB3	1.67±0.09	3.34±0.18	20.62	0.96	**20.80**
4	Newar	WB4	1.82±0.07	3.64±0.14	22.47	1.04	**22.67**
5	Waha	WB5	1.34±0.06	2.68±0.12	16.54	0.77	**16.69**
6	Alwafi	WB6	1.73±0.05	3.46±0.1	21.36	0.99	**21.55**
7	Lojin	WB7	1.61±0.04	3.22±0.08	19.88	0.92	**20.05**
8	Sawa	WB8	1.24±0.03	2.48±0.06	15.31	0.71	**15.44**
9	Alyqein	WB9	1.06±0.02	2.12±0.04	13.09	0.61	**13.20**
10	Alsad	WB10	1.59±0.09	3.18±0.18	19.63	0.91	**19.80**
11	Mina	WB11	1.54±0.06	3.08±0.12	19.01	0.88	**19.18**
12	Nada	WB12	1.49±0.07	2.98±0.14	18.40	0.85	**18.56**
13	Heni	WB13	1.24±0.05	2.48±0.1	15.31	0.71	**15.44**
14	Almazz	WB14	1.58±0.04	3.16±0.08	19.51	0.91	**19.68**

Table 5: The total effective annual dose for people's consumption of water bottled for the districts and regions of Babylon Governorate.

NO. Sample	locally bottled water	Symbols of the sample of bottle water	**ET($\mu Sv.y^{-1}$) ^{238}U**	ET ($\mu Sv.y^{-1}$) ^{235}U	ET ($\mu Sv.y^{-1}$) ^{234}U	Total ET($\mu Sv.y^{-1}$)
1	Aquafina	WB1	0.535	0.026	0.588	**1.149**
2	Afiat	WB2	0.588	0.028	0.646	**1.263**
3	Allueluah	WB3	0.677	0.033	0.744	**1.454**
4	Newar	WB4	0.738	0.035	0.811	**1.585**
5	Waha	WB5	0.543	0.026	0.597	**1.167**
6	Alwafi	WB6	0.701	0.034	0.770	**1.506**
7	Lojin	WB7	0.653	0.031	0.717	**1.402**
8	Sawa	WB8	0.503	0.024	0.552	**1.080**
9	Alyqein	WB9	0.430	0.020	0.472	**0.923**
10	Alsad	WB10	0.645	0.031	0.708	**1.384**
11	Mina	WB11	0.624	0.030	0.686	**1.341**
12	Nada	WB12	0.604	0.029	0.663	**1.297**
13	Heni	WB13	0.503	0.024	0.552	**1.080**
14	Almazz	WB14	0.640	0.031	0.704	**1.376**

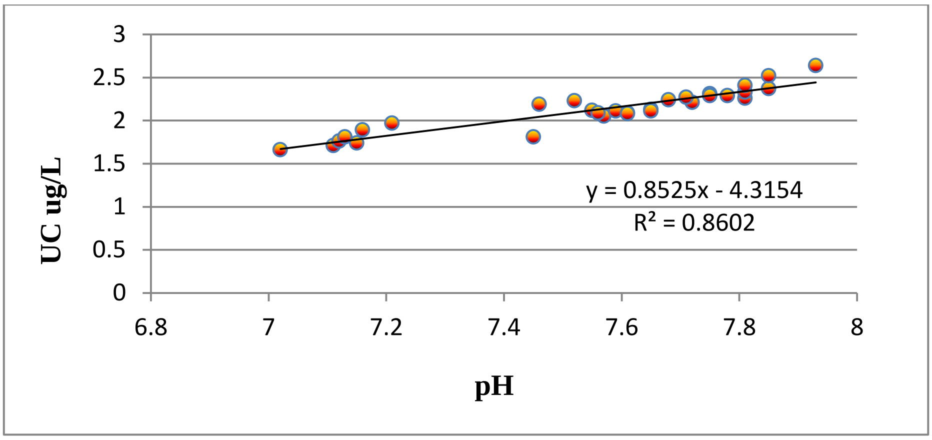

Figure 3: Relationship concentration uranium with pH

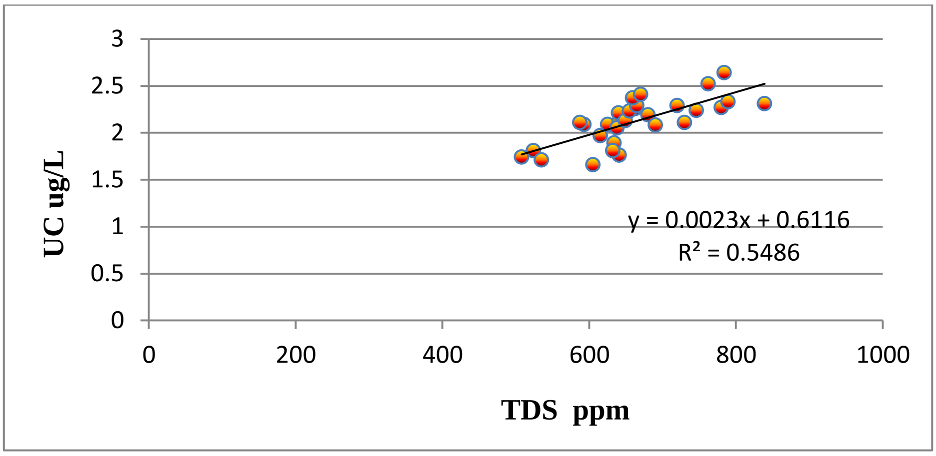

Figure 4: Relationship concentration uranium with TDS.

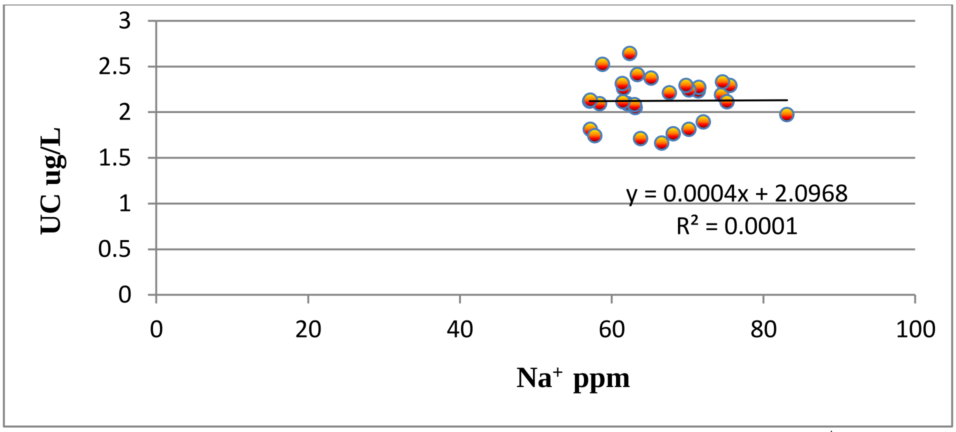

Figure 5: Relationship concentration uranium with Na^+

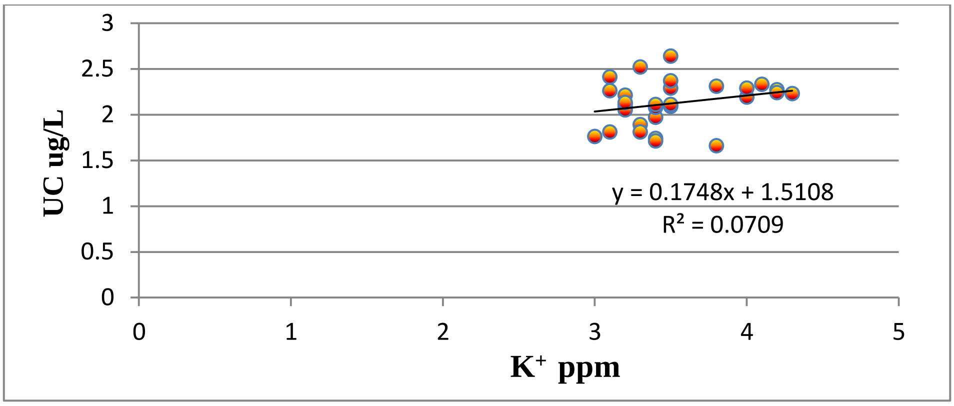

Figure 6: Relationship concentration uranium with K^+

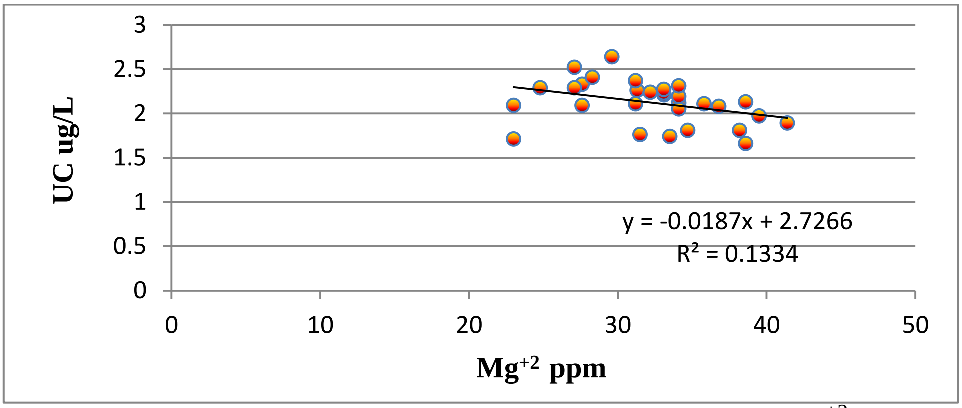

Figure 7: Relationship concentration uranium with Mg^{+2}

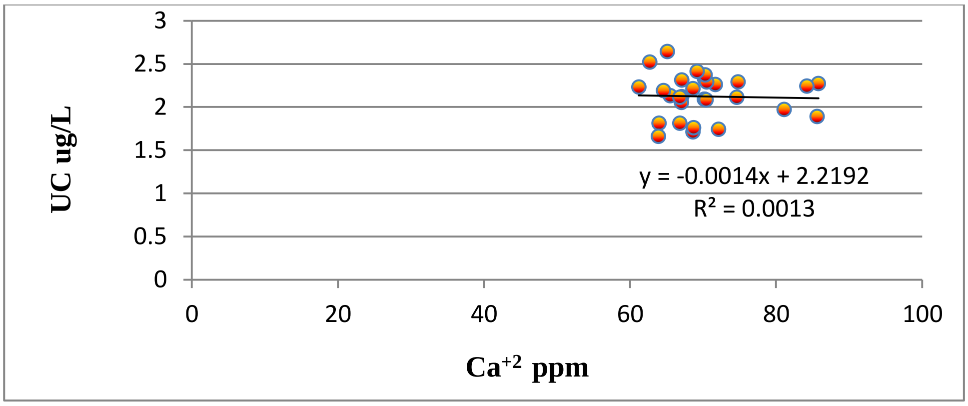

Figure 8: Relationship concentration uranium with Ca^{+2}.

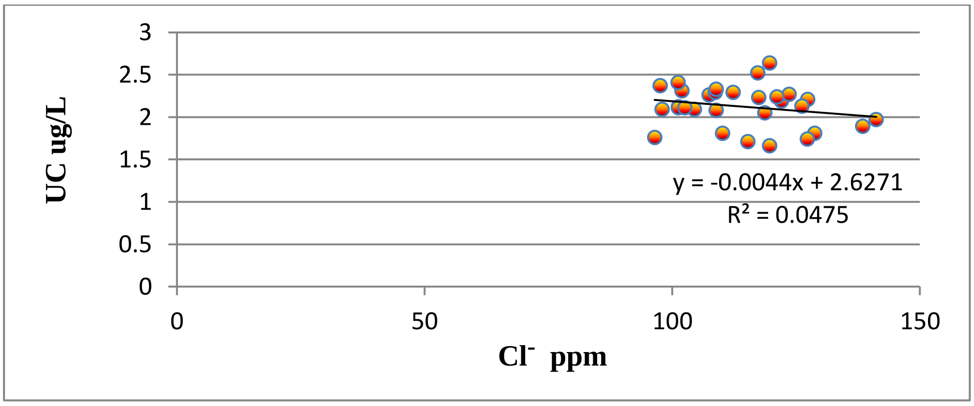

Figure 9: Relationship concentration uranium with Cl^-.

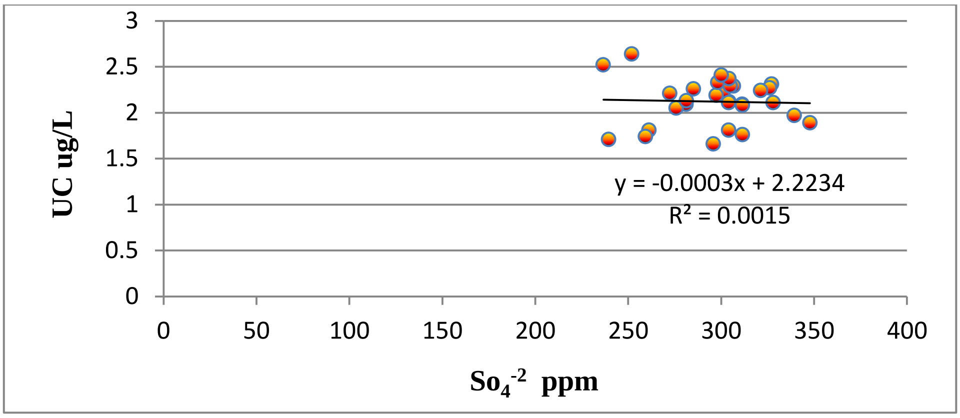

Figure 10: Relationship concentration uranium with So_4^{-2} .

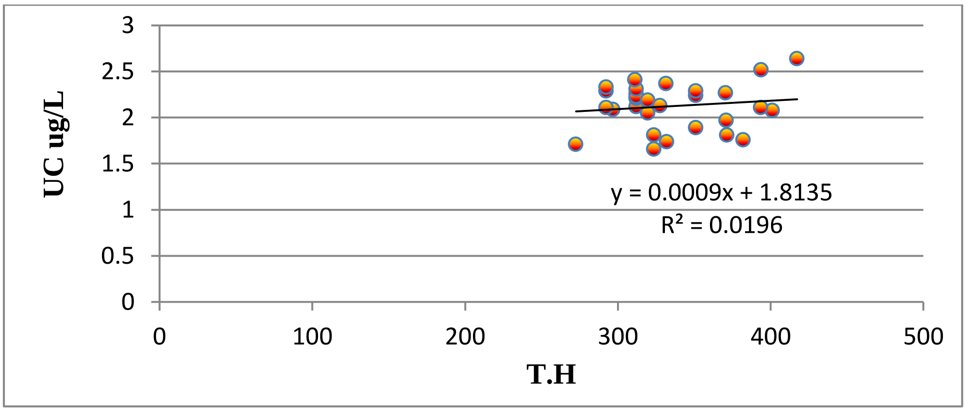

Figure 11: Relationship concentration uranium with T.H.

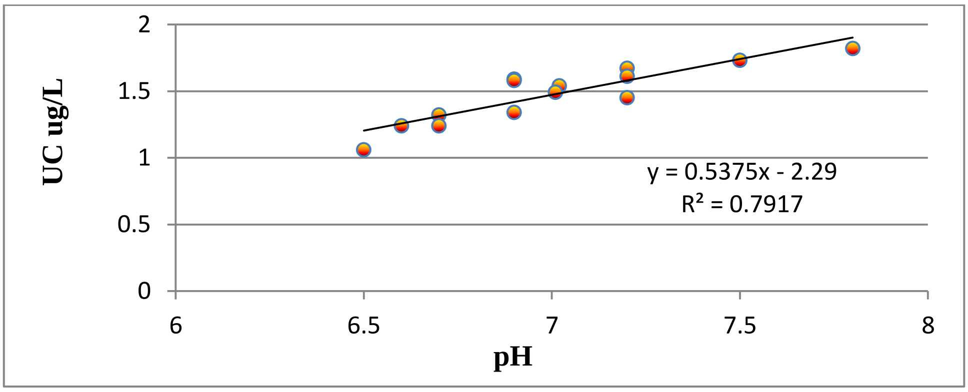

Figure 12: Relationship concentration uranium with pH.

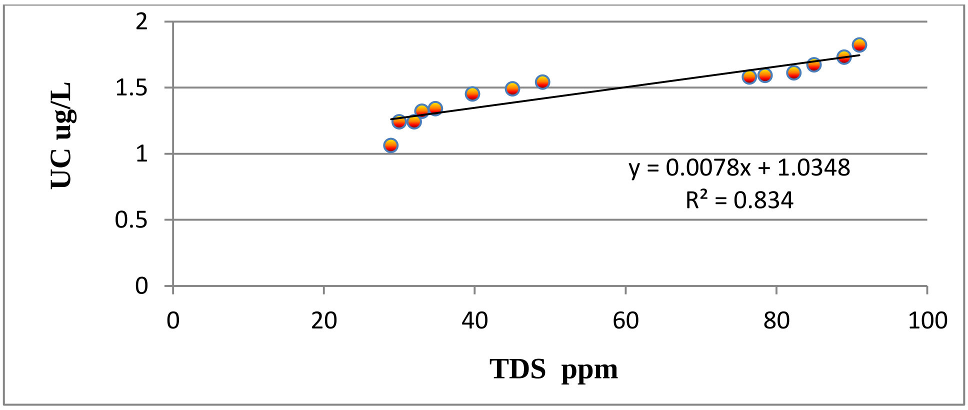

Figure 13: Relationship concentration uranium with TDS.

Conclusions

Through the results, it was found that the concentrations of uranium and its isotopes in bottled water are less than the concentrations found in tap water in samples collected from the districts and regions of Babil Governorate. The water purification processes that are involved in removing suspended solids in filter plants to produce bottled water are more efficient and accurate than in filter plants to produce tap water, and therefore the effective annual dose resulting from the consumption of bottled water is less than the effective dose resulting from the consumption of tap water. In both cases, the annual effective dose resulting from the consumption of this water is less than the internationally recommended dose. By organizations and agencies.

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