Measurement of Background Radioactivity in Baghdad's Main Water Supply Stations: Sediment Samples

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Abstract

Sediment samples were collected from main water processing and supply plants in Baghdad, and tested for radioactivity from both natural and artificial sources. These stations are: East Dijla (Tigris), Al-Kadisia, Al-Karama, Al-Rasheed, Al-Sader, Al-Wathba, and Al-Wihda supply stations. Qualitative measurements were made, and the results showed that most sediments exhibited natural radioactive level and sometimes less than the international regular standards. Specially, K-40 and Ra-226 results were much less than the standards for radioactive concentrations. Ac-228 concentration was found rather than Th-232 (in Al-Sader and Al-Wihda samples) but with low concentrations of about 10-15 Bg/kg and detection confidence ~45% , and Ce-141 and Be-7 both with concentration less than 5 Bq/kg but with confidence ~90%. Cs-137 was detected in 6 of these samples with concentrations varied from 0.84 to 10.42 Bq/kg. All samples measurements were within standard limits providing acceptable radioactivity levels.

Keywords
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قياس الخلفية الإشعاعية في المحطات الرئيسية لمياه الشرب في مدينة بغداد: عينات الرواسب

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الخلاصه

تناول هذا البحث دراسة الملوثات الإشعاعية لبعض المحطات ألرئيسيه لمياه شرب في بغداد فقد جُمعتْ عينات من رواسب الخزانات من محطات تصفية وإنتاج المياه الرئيسية في مدينة بغداد، وفُحصَ مقدار النشاط الإشعاعي فيها والناتج من كلا المصادر الطبيعية والمصنعة. محطات المياه الرئيسية هذه هي: محطة شرق دجلة، محطة القادسية، محطة الكرامة، محطة الرشيد، محطة مدينة الصدر، محطة الوثبة و محطة الوحدة. أُجريتْ القياسات النوعية للعينات وبينت النتائج أن معظم العينات المأخوذة من هذه المحطات تحتوي على نشاط إشعاعي ضمن المعدلات الطبيعية المعتمدة دوليا. أظهرت بعض النتائج معدلات أقل من المعايير الدولية وخصوصا للعناصر المشعة K-40 و Ra-226. في نتائج بعض العينات ظهرت تراكيز المصدر Ac-228 (في عينات محطة مدينة الصدر والوحدة) بدلا من المصدر Th-232 لكن بتراكيز قليلة تراوحت بين (10-15 بكرل\كغم) وبثقة تحسس~ 45% ، والعنصرين Ce-141 و Be-7 وكلاهما بتراكيز أقل من 5 بكرل\كغم لكن بثقة تحسس ~90%. كُشفَ عن تراكيز لعنصر السيزيوم Cs-137 في ستة من المحطات المدروسة وبتراكيز تراوحت بين 0,84 إلى 10,42 بكرل\كغم. جميع نتائج العينات المدروسة بينت أن المعدلات الإشعاعية تقع ضمن المعدلات الطبيعية المقبولة.

Introduction

There are more than 60 radionuclides known to be occurring naturally in the environment. At least 14 radionuclides of them are known to be continually produced in the earth's atmosphere by nuclear reactions between atoms of the earth's atmosphere and cosmic-rays, especially protons.

Radionuclides found in nature are classified into two main groups according to their origin: terrigenous and cosmogenic [1]. Terrigenous radionuclides include long-lived natural nuclides as well as the three natural actinide parent nuclides (chains), Th-232, U-235 and U-238 along with their products (daughters). At least 14 radionuclides are known to occur in nature at present as natural nuclides existing in equilibrium with stable element isotopes. The principal isotopes in this category are K-40 and Rb-87 [1]. The other group of the primitive terrigenous radionuclides includes three actinide parents and their daughters which consist of about 35 radioisotopes such as Pb, Bi, Po, Ra, Ac, Th, Pa, and U. Uranium decay series, characterized by mass numbers of 4n+2, includes more familiar radionuclides encountered in the marine environment. Cosmogenic radionuclides include H-3 (tritium) and C-14 as principal members.

The artificial radionuclides which are often found in the marine, costal, and river environments are classified into the following types depending on their mode of production: light nuclides, fission products, and activation products. Light nuclei include: H-3 and C-14. Fission products include:Cs-144, Cs-137, Ru-106, Sr-90, Tc-99, Eu-155, I-131, Nb-85, Zr-85, Ru-103, Sb-125 and Sr/Y-90. Activation nuclei include: Cs-134, Cr-51, Co-60, Mn-54, Ag-110, and Zn-65.

Pollution in different environmental resources has received an increasing attention in recent years, since the advances in technological development were always associated with an increase in different types of polluters. Specially, contamination due to radioactive polluters resulting from both natural and artificial sources received special interests. Due to its nature and increased applications in modern industrial and medical use, pollution due to radioactive materials is required to be monitored and observed regularly, or immediately after related events such as wars and massive contamination accidents [1].

In Iraq, the issue of radioactive pollution received special interests especially after the wars of 1991 and 2003. Many studies had been made that dealt with the radioactive pollution in the Iraqi environment. However, a diversity of most of these studies were not categorized nor organized in a standard form to unify the methods of measurements and detection, sampling, and comparison with local standards. This resulting in an absence of standard regulations or guidelines that may serve as a standard reference for qualitative studies performed to investigate the Iraqi environment specifically. Nevertheless, many of these studies indicated natural or normal radioactive levels in most of the local environment. These studies mostly involved the effects of depleted uranium (DU) on the Iraqi environment [2-5], among other natural and artificial radioactive sources [6-7], as well as other contamination (biological and chemical) types [8].

The basic routine that is regularly used to study radioactive pollution in water and other environmental samples is [1,9] to quantitatively determine the existence of gross alpha and beta emitters in the samples. If the concentration of these emitters was found larger than a threshold value, more qualitative measurements must be carried out in order to determine the concentration of each radioactive element separately. After that, one may judge the samples whether they are radioactively polluted or not from comparing the results with standard regulations.

These regulations vary according to the geographic location as well as the nature of the samples. However, international standards are agreed by the WHO and the IAEA for the three types of pollutions (chemical, biological and radiological pollutions) [1]. Thus, there are two types of standard regulations: those of the WHO (with international acceptance) and those specified locally for each country. Examples of the latter are the USEPA Standards (United States Environmental Protection Agency) [10], the European standards [11] and the Australian standards [12]. Pollution detection limits may exceed local standards and still considered somewhat safe, but if these limits exceeded the WHO ones, immediate procedures must be firmly and seriously considered to treat contaminated areas.

In present work, the sediments' samples are studied qualitatively. In addition to the levels of radioactive nuclei, that found in sediment samples collected from the major water refinery and processing plants was investigated. These plants are: East Dijla (Tigris), Al-Kadisia, Al-Karama, Al-Rasheed, Al-Sader, Al-Wathba, and Al-Wihda plants. In Table (1) the production capacity of each of these refinery plants is listed.

Samples Preparation and Detection Method

Each sample with different mass was measured against radioactive contamination using high-purity germanium (Ge) detectors with standard setup. Samples' measurements were made at the Iraqi Center for Radiation Protection (ICRP). The multichannel analyzer was suitably set to the range (1-4092) channels, thus providing an appropriate range for the detection process with an acceptable overall FWHM resolution (Table 2-A).

Accumulation time for all samples was one hour. The analysis of the collected spectra passed the statistical criteria specified by the code (GENIE 2000) [13]. In Table (2-B), a typical statistics of the Al-Kadisia samples' report is illustrated.

Table (1). The Main Water Refinery and Supply Stations in Baghdad [14] (arranged according to production capacity).

Water Refinery Station	Production Capacity ($x10^3$ liters per day)	Coverage Area (Baghdad City)
East Dijla (Tigris)	765	Provides most of the area eastern Tigris river
Al-Karama	230	Supplies Al-Kadhimia, Al-Rahmania and Al-Utaifia
Al-Kadisia	135	Provides Al-Kadisia, Al-Yermouk and part of middle Baghdad
Al-Wathba	118	Provides most of Al-Rusafa district and Al-Adhamya
Al-Sader	90	Dedicated to Al-Sader city
Al-Wihda	80	Provides Al-Karadah and Al-Masbah
Al-Rasheed	60	Provides Al-Rasheed and Al-Zo'farania

Table (2-A). A Typical Statistics of the Spectrum Analysis for the Al-Kadisia Samples. Statistical Sheet.

Peak No.	Peak Centroid (channel)	Energy (keV)	FWHM (keV)	Net Peak Area (counts)	Net Area Uncertainty (counts)	Continuum (counts)
1.	40.05	20.33	0.29	1.17E+001	1.75	9.19E+000
2.	43.97	22.29	0.30	2.71E+001	2.96	9.55E+000
3.	56.32	28.46	0.32	1.11E+001	3.04	1.73E+001
4.	69.08	34.83	15.92	4.90E+001	15.41	8.00E+001
5.	155.07	77.79	1.05	2.88E+002	30.34	3.06E+002
6.	292.00	146.20	0.50	3.09E+001	16.88	1.33E+002
7.	373.31	186.82	1.49	1.84E+002	25.93	2.16E+002
8.	478.29	239.27	1.28	8.29E+002	31.17	1.45E+002
9.	484.35	242.29	1.29	1.50E+002	14.78	1.30E+002
10.	591.41	295.78	1.35	1.66E+002	22.32	1.46E+002
11.	677.62	338.85	1.19	1.47E+002	20.51	1.15E+002
12.	704.85	352.45	1.38	3.61E+002	24.75	1.05E+002
13.	926.92	463.39	1.65	6.81E+001	13.60	4.89E+001
14.	955.75	477.81	0.90	2.60E+001	11.92	5.80E+001
15.	1022.31	511.04	1.09	6.42E+001	13.37	5.08E+001
16.	1167.63	583.64	1.33	2.41E+002	17.90	3.30E+001
17.	1219.64	609.62	1.42	2.93E+002	19.15	3.19E+001
18.	1324.52	662.02	1.47	3.32E+002	20.23	3.18E+001
19.	1455.62	727.51	1.14	5.93E+001	10.91	2.28E+001
20.	1723.21	861.19	0.58	2.74E+001	8.12	1.76E+001
21.	1823.83	911.46	1.68	1.74E+002	16.01	3.26E+001
22.	1939.56	969.27	1.35	6.51E+001	12.70	3.89E+001
23.	2242.56	1120.64	1.97	7.00E+001	11.73	2.70E+001
24.	2818.99	1408.61	1.43	9.93E+000	4.50	5.07E+000
25.	2942.97	1461.56	1.97	7.69E+002	28.31	1.13E+001
26.	3534.27	1765.95	2.07	5.96E+001	8.11	2.75E+000

Table (2-B). A Typical Statistics of the Spectrum Analysis for the Al-Kadisia Sample. Efficiency Sheet.

Peak No.	Energy (keV)	Peak Efficiency	Efficiency Uncertainty
1.	20.33	6.41E-003	4.33E-003
2.	22.29	9.04E-003	5.25E-003
3.	28.46	1.92E-002	7.23E-003
4.	34.83	3.08E-002	7.67E-003
5.	77.79	6.97E-002	2.25E-003
6.	146.20	6.24E-002	2.01E-003
7.	186.82	5.43E-002	1.75E-003
8.	239.27	4.58E-002	1.54E-003
9.	242.29	4.54E-002	1.53E-003
10.	295.78	3.90E-002	1.38E-003
11.	338.85	3.50E-002	1.26E-003
12.	352.45	3.39E-002	1.23E-003
13.	463.39	2.72E-002	9.43E-004
14.	477.81	2.66E-002	9.09E-004
15.	511..04	2.52E-002	8.34E-004
16.	583.64	2.26E-002	6.87E-004
17.	609.62	2.19E-002	6.41E-004
18.	662.02	2.05E-002	5.57E-004
19.	727.51	1.91E-002	4.68E-004
20.	861.19	1.67E-002	3.39E-004
21.	911.46	1.60E-002	3.07E-004
22.	969.27	1.53E-002	2.78E-004
23.	1120.64	1.37E-002	2.38E-004
24.	1408.61	1.15E-002	2.19E-004
25.	1461.56	1.12E-002	2.17E-004
26.	1765.95	9.67E-003	2.02E-004

Results

Table (3) summarizes the entire results of the present study. The radionuclides are arranged in this table similar to those found in the Survey Concentration Ranges and Typical U.S. Background Concentrations of Radionuclides [15] listed in Table (4) for better comparison. The studies water supply stations are indicated on Baghdad's map in Fig.(1).

Discussions

A general comparison of the present results with those of ISCORS [15] shows that the activity of all redionucleis concentrations detected in the selected samples are within acceptable range.

Results of K-40 can be assumed as a good measure of the acceptance of the results when calculating the natural radioactivity. The present results of K-40 are particularly comparable with those of many other researches (13). The present results varied from 216.35 ± 9.2 Bq/kg (from Al-Kadisia station) to 614.85 ± 24.85 Bq/kg (Al-Wathba station) with average 377.12±16.92 Bq/kg. Earlier results varied from 142.57 ± 5.14 Bq/kg to 937.21 ± 19.09 Bq/kg with average 527±12.79 for river sediments of Akoko rivers of Nigeria [16], from 146 to 500 Bq/kg with average 323 Bq/kg for sediments taken from the Northwestern Iranian coasts of the Arab Gulf [17], from 30 to 1110 Bq/kg with average 570 Bq/kg for sediments taken from Columbia River, USA [18], 500±100 Bq/kg from sediment samples from the Dobczyce Drinking Water Reservoir, Poland [19], and from 40.94 to 189.58 Bq/kg with average 115.26 from sediments taken from bottom sediments of a tin mine in Malaysia [20]. From comparing the present results with those, one can safely assume that the local limits are within most international results.

The present results of Ra-226 were 24.04±2.66 Bq/kg (Al-Sader) to 38.08±6.87 Bq/kg (Al-Wihda). The average was 31.39±5.43 Bq/kg. These results are also comparable with those of Ajayi 7.64±0.8 to 52.71±0.97 Bq/kg with average 17.42±0.68 Bq/kg [16], 15.5 to 48.1Bq in Colombia River [18], and 40.94-189.58 Bq/kg [20]. Also, it can be clearly seen that the present results are within the international range.

Furthermore, one can calculate the radiological effect (or health effect) of the natural radioactivity of the sediments from the Radium Equivalent Activity (REA). This represents a measure of the activity of the three radionuclear active series, namely: K-40, Th-232 and U-238. REA also reflects the equilibration of U-238 with its daughter Ra-226 and of Th-232 with its daughter Ac-228 [16]. This index can be calculated from the following formula:

$$REA(Bq/kg) = A_{Ra}(Bq/kg) + 1.43 \times A_{Th}(Bq/kg) + 0.077 \times A_{K}(Bq/kg), \quad (1)$$

where ARa, ATh and AK are the activities of Ra-226, Th-232 and K-40, respectively.

Another factor that could be determined from the present measurements is the calculation of the Total Air Absorbed Dose Rate, Dair, which is found from, for a height of 1 meter above the ground [21]:

$$D_{air}(nGy/h) = 0.427 \times A_{Ra}(Bq/kg) + 0.662 \times A_{Th}(Bq/kg) + 0.034 \times A_{K}(Bq/kg), \quad (2)$$

The units of Dair are nano-Gray/hour (nGy/h).The Annual Outdoor Dose-Equivalent to humans,H, can also be found from the present measurements by [16]:

$$H(nGy/h) = 0.2 \times 8760(h) \times 0.7(Sv/Gy) \times D_{air}(nGy/h), \quad (3)$$

where the factor 0.2 is used to express outdoor dose, the factor 0.7 is a conversion factor from Severt to Gray (Sv/Gy), and D_{air} is found from(2).

Table (3). The Results of the Present Study…

East Dijla (Tigris)			
Radio-nuclide	radioactivity Bq/kg[1]	uncertainty Bq/kg	conf %
Be-7[#]			
Bi-212	9.35	1.80	48.4
Bi-214	10.15 + 12.33	0.68 + 1.95	37.1
Cs-137	7.51	0.45	99.8
K-40*	244.60	9.30	97.9
Pa-234m*			
Pb-212*	7.25 + 11.8	0.80 + 0.60	51.4
Pb-214*	11.85 + 15.0 + 9.27 + 10.1	1.31 + 1.44 + 1.35 + 0.68	69.8
Ra-223*			
Ra-224*			
Ra-226*	29.80	5.42	97.7
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	4.12 + 3.32	0.81 + 0.29	
U-234*			
U-235*	1.81	0.33	36.2
U-238*			
Ac-228[#]			
Ce-141[#]			

[1] **Bq/kg= Becquerel / kilogram**
[#] **Isotopes are not found in ISCROS survey [15]**
[*] **Naturally Occurring Isotope**

Al-Kadisia			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7 [#]	3.20	1.40	99.2
Bi-212	8.80	1.64	47.6
Bi-214	9.70 + 11.40 + 11.70	0.71 + 2.01 + 5.30	39.2
Cs-137	6.41	0.43	97.9
K-40*	216.35	9.20	91.4
Pa-234m*			
Pb-212*	7.96 + 13.60	0.80 + 0.70	50.4
Pb-214*	13.0 + 14.90 + 7.50 + 9.60	1.43 + 1.40 + 1.0 + 0.70	68.9
Ra-223*			
Ra-224*			
Ra-226*	34.70	5.00	94.3
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	3.97 +4.16 + 4.58	0.80 + 0.30 + 1.30	82.9
U-234*			
U-235*			
U-238*			
Ac-228[#]			
Ce-141[#]	0.35	0.20	91.2

Table (3). The Results of the Present Study (*continued*)…

Al-Karama			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7			
Bi-212	17.80	6.20	42.5
Bi-214			
Cs-137	10.42	1.30	98.5
K-40*	553.14	32.60	89.3
Pa-234m*			
Pb-212*	5.60 + 19.90	2.6 + 2.10	50.8
Pb-214*	9.30+17.2+ 15.1	4.30+2.9+2. 1	54.6
Ra-223*			
Ra-224*			
Ra-226*			
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	17.32 + 7.73	3.2 + 1.02	69.6
U-234*			
U-235*			
U-238*			
Ac-228#			
Ce-141#	2.23	0.54	91.2

Al-Rasheed			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7 #			
Bi-212			
Bi-214	10.50 + 7.96 + 15.03	0.99 + 2.78 + 2.41	52.0
Cs-137			
K-40*	450.70	16.80	94.8
Pa-234m*			
Pb-212*			
Pb-214*	9.96+13.10	1.50+1.00	31.2
Ra-223*			
Ra-224*			
Ra-226*	32.60	7.20	96.8
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	10.4 + 3.03	1.46 + 0.43	73.3
U-234*			
U-235*	1.93	0.44	34.9
U-238*			
Ac-228#			
Ce-141#			

Table (3). The Results of the Present Study (*continued*)…

Al-Sader			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7#			
Bi-212	11.53	1.36	47.6
Bi-214	9.3+11.03+ 11.45	0.61+1.35+ 1.5	52.0
Cs-137	0.84	0.14	99.9
K-40*	219.00	8.76	96.8
Pa-234m*			
Pb-212*	8.2+5.45+1 0.4	0.88+0.52+ 0.94	70.4
Pb-214*	12.40+8.90 +15.50+9.5 0+10.50	1.3+.85+1.4 +.75+.65	84.3
Ra-223*			
Ra-224*			
Ra-226*	21.04	2.66	96.3
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	3.30+3.50	0.53+0.26	73.9
U-234*	218.70	57.10	49.9
U-235*	1.27	0.16	34.4
U-238*			
Ac-228#	9.16+8.3+6 .3+11.20 +10.3+12.5	1.67+1.00+ 2.1+0.93 +2.3+1.34	45.1
Ce-141#			

Al-Wathba			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7#			
Bi-212			
Bi-214	16.0 + 17.8 + 19.5	1.45+7.76	43.1
Cs-137	5.10	0.71	99.6
K-40*	614.85	24.85	93.9
Pa-234m*			
Pb-212*	3.63+1.67	1.40+1.09	49.3
Pb-214*	5.94 + 33.2 + 14.6 + 17.3	2.3+3.3+2.1 +1.47	68.8
Ra-223*			
Ra-224*			
Ra-226*			
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	9.98+4.96	1.85+0.65	73.4
U-234*			
U-235*			
U-238*			
Ac-228#			
Ce-141#			

Table (3). The Results of the Present Study (*continued*)…

Al-Wihda			
Radio-nuclide	radioactivity Bq/kg	uncertainty Bq/kg	conf %
Be-7 #			
Bi-212	17.00	3.03	43.9
Bi-214	16.4 + 16.5	1.20 + 3.31	33.1
Cs-137	4.92	0.57	94.0
K-40*	341.20	?	?
Pa-234m*			
Pb-212*	15.50	?	?
Pb-214*	14.90	?	?
Ra-223*			
Ra-224*			
Ra-226*	38.80	6.87	93.3
Ra-228*			
Th-227*			
Th-228*			
Th-230*			
Th-232*			
Th-234*			
Tl-208*	5.19 + 5.26	1.62 +0.52	68.2
U-234*			
U-235*			
U-238*			
Ac-228#	15.5	?	?
Ce-141#			

In Table (5), the calculated indices REA, D_{air}, and H are listed for the selected water supply stations of Baghdad.

A better and more complete comparison can be seen from Table (6) [21] where the present results of sediments are compared with soil results, as in [17], to have a clear insight aboutthe comparability of the detection limits. Note that radioactivity due to Th-232 and U-238 isotopes were not detected in all the present samples.

Cs-137 and Be-7 are considered as artificial isotopes, since their existence in nature is not likely at all due to natural radioactivity [1,17,22]. Current results of Cs-137 varied from 0.84±0.14 Bq/kg (from Al-Sader station sediments) to 10.42±1.30 Bq/kg (Al-Karama). The average value is 5.86±0.60 Bq/kg. The earlier results were: 3.7 to 9.62 Bq/kg for soil from ISCROS standards [15], the Iranian side of the Arab Gulf from 5 to 20 Bq/kg [17], Dobczyce drinking water reservoir, Poland, from 1.1 to 6.5 Bq/kg [19], Curonian Lagoon in Lithuania, from 9-207 Bq/kg [23], and in Asian Arctic, Russian side the readings varied from 1.4 to 86 Bq/kg in reactor control area, to 1.5-86,700 Bq/kg in affected areas (close to the Russian power reaction in that area) [24]. Thus, present experiment results are within the range of safe regulations. However, it would be of great importance to make more careful analysis for this radionucleus alone with different depths since such measurements will exactly show its affectivity in sediment samples.

Conclusions

Two conclusions can be reached from the present results: the first is that the radioactivity found in sediment samples from 7 out of the 9 water refinery stations in Baghdad are within most of the international standards. The second is that Cs-137 concentrations are detected in most of the samples, although with low concentrations. Thus, it is concluded and recommended that more careful analysis of this isotope must be made taken into account the variation of its concentration with depth.

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Table (4). Survey Concentration Ranges and Typical U.S. Background Concentrations of Radionuclides [15].

Radionuclide	Ash Concentrations Bq/kg		Sludge Concentrations Bq/kg		Building Materials Bq/kg		Phosphate Fertilizer Bq/kg		Soil Bq/kg	
	From (1)	to	from	to	from	to	from	to	from	to
Bi-212	0	592	0	481	3.7	136.9	3.7	170.2	3.7	129.5
Bi-214	0	592	0	592	92.5	186.85	148	5180	3.7	140.6
Cs-137	0	13.69	0	133.2	NDA (2)	NDA	NDA	NDA	3.7	9.62
K-40*	273.8	814	0	962	29.6	1110	1184	59496	99.9	703
Pa-234m*	0	2849	0	999	7.4	186.85	148	5180	3.7	140.6
Pb-212*	13.32	555	0	555	3.7	136.9	3.7	170.2	3.7	129.5
Pb-214*	22.57	592	0	629	7.4	185	148	5180	3.7	140.6
Ra-223*	3.7	29.6	0	3.33	3.7	9.25	7.4	244.2	< 3.7	7.4
Ra-224*	0	181.3	0	444	3.7	137.64	3.7	170.2	3.7	129.5
Ra-226*	0	814	0	1739	3.7	129.5	3.7	888	3.7	140.6
Ra-228*	24.05	1110	0	1406	3.7	137.64	3.7	170.2	3.7	129.5
Th-227*	0	40.7	0	18.5	3.7	7.4	7.4	244.2	< 3.7	7.4
Th-228*	0	518	2.59	333	3.7	136.9	3.7	170.2	3.7	129.5
Th-230*	0	96.2	3.33	62.9	7.4	185	148	5180	3.7	140.6
Th-232*	0	62.9	0.74	59.2	3.7	136.9	3.7	170.2	3.7	129.5
Th-234*	0	2960	0	851	7.4	185	148	5180	3.7	140.6
TI-208*	0	518	0	177.6	3.7	136.9	3.7	170.2	3.7	129.5
U-234*	44.4	3367	6.66	1628	7.4	185	148	5180	3.7	140.6
U-235*9	0	125.8	0	114.7	3.7	7.4	7.4	244.2	< 3.7	7.4
U-238*	29.6	2738	6.66	962	7.4	186.85	148	5180	3.7	140.6

* Naturally occurring radionuclides (1) Values less than 3.7 Bq/kg are rounded to zero in all concentrations [15]. (2) NDA: No Data Available

Table(5). The calculation indices of REA, D_{air} and H from the present results.

Water Refinery Station	REA (Bq/kg)	D_{air} (nGy/h)	H (nGy/h)
East Dijla (Tigris)	48.63	21.04	25804
Al-Kadisia	51.36	22.17	27192
Al-Karama	42.59	18.80	23064
Al-Rasheed	67.30	29.24	35864
Al-Sader	37.90	16.43	20149
Al-Wathba	47.34	20.90	25637
Al-Wihda	65.07	21.16	34545
Averages:	**51.45**	**21.39**	**27465**

Table(6). Summary of activity concentrations and dose rates of natural radioisotopes in soil samples in some of the world regions [17,21].

Region	K-40 (Bq/kg)		Th-232 (Bq/kg)		U-238 (Bq/kg)		Ra-226 (Bq/kg)		Dose rate(nGy/h)	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Bangladesh	130–160	350	–	–	–	–	21-43	34	–	–
China	9-1800	440	16–200	41	2-690	33	2–440	32	2–340	62
Hong Kong	80-1100	530	1-360	95	25–130	84	20-110	59	51-120	87
India	38–760	400	14–160	64	7–81	29	7–81	29	20–1100	56
Japan	15–990	310	2-88	28	2-59	29	6–98	33	21-77	53
Kazakhstan	100-1200	300	10–220	60	12-120	37	12-120	35	10–250	63
Korea	17-1500	670	–	–	–	–	–	–	18-200	79
Malaysia	170–430	310	63-110	82	49–86	66	38–94	67	55-130	92
Thailand	7–712	230	7–120	51	3-370	114	11-78	48	2–100	77
USA	100-700	370	4-130	35	4–140	35	8–160	40	14-118	47
Syria	87–780	270	10-32	20	10-64	23	13-32	20	52–67	29
Turkey	125-570	340	4-90	37	7-200	21	–	–	–	–
Pakistan	525–602	562	45–53	49	25–28	26	25–28	26	18-93	65
Egypt	29-650	320	2-96	18	6–120	37	5-64	17	8–93	22
Croatia	140–710	490	12–65	45	83-180	110	21–77	54	–	–
Cyprus	0-670	140	–	–	–	–	0-120	17	9–52	18
Greece	12–1570	360	1-190	20	1–240	25	1-240	25	30-109	56
Portugal	220-1230	840	22–100	51	26-82	49	8–65	44	4–230	84
Russia	100-1400	520	2-79	30	0–67	19	1-76	27	12-102	65
Spain	25–1650	470	2–210	33	–	–	6–250	32	40–120	76
Arab Gulf (Iranian side)	146-500	395	15-45	26	21–65	41	17-48	35	19-58	38
Baghdad (Sediments) *	216-614	377	–	–	–	–	24-38	31	16-29	21.4

*** Present Study**

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Fig. (1).The geographic map of Baghdad city. The studied supply stations are indicated.