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EVALUATION OF QUALITY OF DRINKING WATER FROM BAGHDAD, IRAQ

*BARBOOTI, M. M[1+].; BOLZONI, G[2].; MIRZA, I. A[3]..; PELOSI M[2].
BARILLI, L[2].; KADHUM, R[3].; & PETERLONGO, G[2].

[1]School of Applied Sciences, University of Technology, Baghdad, Iraq.
[2]Water and Sanitation Team for the Emergencies - Italian Red Cross Macaque Laboratories - Milan - Italy
[3]Environmental Analysis Department, Ministry of Environment, Baghdad, Iraq.

+Present Address: Department of Earth and Environmental Studies,
Montclair State University, Normal Avenue 1,
Montclair, NJ 07043, USA.
*aldhaherim@mail.montclair.edu

ABSTRACT

This is a joint work between the Italian Red Cross and the Environmental Laboratories, Baghdad. The drinking water (DW) samples from 16 residential districts in Baghdad were chemically evaluated with reference to the raw water samples and water directly taken from the purification plants. In addition to the routinely measured parameters, 17 metals and 11 trihalomathane (THM) were measured. Generally, the samples of water analysed can be considered of good quality. The relatively high sulphate and aluminium contents results from the use of aluminium sulphate as flocculent. The ammonia and Nitrite concentrations were lower than the detectable limit, because ammonia is converted into chloramines and nitrite is converted into Nitrate during chlorination. This indicates no sewage contamination of the drinking water. The high chloride contents can be referred to the use of partially degraded hypo for the disinfection. The presence of THM's in the samples analysed is indicative of good disinfection process. The presence of these compounds is preferred better than bacterial contamination. The relatively high levels of zinc and iron have no impact on the quality of DW. Iron, however, was efficiently removed during the treatment, together with Manganese. Reference was done to the EU specification of drinking water regarding total hardness, chloride contents, sulphate, iron and THM's. As for the iron content, the original pH of the river water (7.5 and 8.0) ensures that Iron should not be present in soluble form at a detectable level. Corrosion of the pipes could be one of the reasons for the presence of iron.

***Key Words**: Drinking water quality, heavy metals, sulphate, Aluminium, Trihalomethans, hardness.*

INTRODUCTION

Many techniques are used to remove pollutants, suspended matter and microbial agents from the water body. The regulations controlling the acceptable levels of water quality parameters are always updated to fulfill health standards. The monitoring of drinking water (DW) quality is receiving increasing interest and analytical methods are developed to improve the sensitivity and detection limits for various analytes. However, DW, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk.

The DW is taken from rivers, lakes, reservoir, spring and wells. Along the trip of water over the surface land, some components of rocks and soil may dissolve and carried to the final consumer. Organic and inorganic contaminants may be introduced to DW sources from industrial processes, petroleum production and refining and domestic activities. The production of DW involves processes that remove suspended matter disinfection to remove biological agents. The appearance, taste or odors of water from a well or other sources offer some information on obvious contamination but chemical analysis is needed to detect water contamination. Obvious contaminants include silt (turbidity) and hydrogen sulfide, which can be detected by smell (Self, 1996). In some communities, the quality parameter levels of natural waters fall within the permissible limits that no treatment was necessary to use it as DW (Akoto & Adiyiah, 2007).

Disinfection is an important and necessary step in the water treatment process to protect against harmful bacteria and other possible contamination. Chlorine is the most widely used and approved disinfectant in Iraq and most countries including the United States. Disinfection of water with chlorine introduced a major category of contaminants, the trihalomethanes, as a result of the action of chlorine on the organic contaminants (WHO, 2005, Singer, 2006; Tanglewood Water System, 2007).

When the DW standards are usually issued, they are used for governing drinking water quality and reporting requirements for public water systems (NSF International, 2000). Water contaminants may originate from the treatment chemicals, if their quality grades are not within the standards (Water Supply Division, 2005). Studies on DW quality monitoring reveal major gaps in the system of public health protections when it comes to tap water safety (Environmental Working Group, 2005) and to prevent water pollution and protect the sources of DW.

Vodela *et al.,* (1997), studied the effects of contaminants like arsenic, cadmium, lead, benzene and trichloroethylene on reproductive performance, egg quality, and embryo toxicity in broiler breeders. They showed a linear relationship between increasing concentration of the chemical mixture in drinking water and decreasing body weight of hens. Low concentration of the chemical mixture significantly decreased egg production and egg weight, and increased percentage embryonic mortality. These results suggest that reproductive function in hens is sensitive to adverse effects of contaminated drinking water.

The pollution with toxic metals is a serious concern; because potential contamination of drinking water sources can originate from soil contamination. Some heavy metals have bio-importance as trace elements but, the biotoxic effects of many of them in human biochemistry are of great concern. Hence, there is the need for proper understanding of the conditions, such as the the concentrations and oxidation states, which make them harmful, and how biotoxicity occurs (Duruibe, 2007).

Squillqace, et al. studied the determination of volatile organic compound, VOCs, pesticides, Nitrate and their mixtures in groundwater used for drinking Water (Squillqace, 2002). Nitrate at levels above 45 mg/L is a health risk for infants of less than six months of age and pregnant women with certain specific enzyme deficiencies. Nitrate can interfere with the capacity of blood to carry oxygen (Squillqace, *et al.,* 2002).

Fluoride has beneficial effects on teeth at low concentrations in DW, but excessive exposure to fluoride in drinking-water, can give rise to a number of adverse effects. These ranges from mild dental fluorosis to crippling skeletal fluorosis which is a significant cause of morbidity (Fawell, *et al.,* 2006). The significance and health effects of some water pollutants and ingredients like sulfate, lead, fluoride, nitrate and organic compounds have been reported (Kendall, 1992).

In Iraq, the municipalities are responsible for the production and delivery of drinking water (DW). During 2004 and 2005 the quality of DW in Iraq was greatly deteriorated because of the war operation in this country. The analytical laboratories of the environment and water and health authorities carry out chemical and bacteriological test on DW in Iraq. The failure of the analyzed water samples reached about 40% of the collected samples Barbooti, *et al.,* (2005). Some efforts were put to improve the infrastructure and reconstruction of DW treatment systems. Many projects were established in Iraq to supply bottled DW and manufacture of home water clarification, disinfection units in Iraq. A comprehensive study was carried out during 2006 for the evaluation of bottled DW and home purification units. Some bottled DW failed to match the minimum contaminant level (Barbooti, et al., 2006. Ion chromatography was used successfully for the determination of major anions, PO_4^{3-}, SO_4^{2-}, NO_3^-, NO_2^-, Cl^-, Br^- and F^- in drinking water samples from Baghdad area and Kualalampur (Alsudani, *et al.,* 2009).

Soylak *et al.,* 2002, studied the determination of metal ions in the drinking water samples from Yozgat, Turkey. They concluded that the concentrations of the investigated major ions and metal ions in the drinking water samples were below the guidelines for DW standards (Water Pollution Control Regulation of Turkish Authorities, 1989 and WHO, 2004. No correlations were found between metal concentrations in the drinking water samples (Soylak *et al.,* 2002).

It is the aim of the present work to make a comprehensive evaluation of the chemical parameters of the DW supplied to the homes in Baghdad area from the many water stations controlled by the Baghdad Amanat. The present work is a collaborative investigation on the levels of chemical pollutants in drinking water supply of Baghdad in cooperation with Esercizio Acque Reflue e Laboratori CAP Gestione spa Labratorio di Analisi – Milano – Italy.

MATERIALS AND METHODS

Sampling: Twenty seven water samples were collected for this study. Fifteen samples were taken from homes (Residence), 6 samples were freshly produced DW from the production stations and the remaining six were taken from the location of water intake from the river to these stations. The 15 residential locations represent both the eastern and western sides of Tigris River (Table 1). The locations of water production stations are displayed in Fig. 1.

TABLE 1. NAMES OF LOCATIONS WHERE RESIDENTIAL SAMPLES WERE COLLECTED

Al Atifia 409/20/42
Al Jehad 889/28/31
Al Zoufrania 954/54/13
Al Mahmodia 14th Ramadan 22/7
Al Talbia 323/28/2
Al Mahmodia 17th July 69/106
Al Kadhmia
Al Shaab 337/19/83
Al Amine 2end 741/36/15
Al Karada 903/12/5
Al Kadsia 602/8/50
Al Salehia 28 April building
Palestine Street 503/34/19
Al Sadir 529/28/11
Al Kadsia 604/5/3

FIG. 1. DISTRIBUTION OF THE DRINKING WATER (DW) PRODUCING STATIONS WITHIN BAGHDAD AREA.

Induced Coupled Plasma analysis: The determination of metals was carried out using induce couple plasma optical emission spectroscopy (ICP-OES) on Varian/Vista-AX ICP-AES. High-purity nitric acid (HNO_3 60%, from Merck) was used. Deionized water (with 18 MΩ-cm resistance) were used for dilution and preparation of standard solution. The calibration standards were prepared by diluting multi-element stock standards (Inorganic Ventures, Inc., Lakewood, NJ, USA) with 1% v/v HNO_3, and working standards of below 10 µg/L were prepared immediately before the measurement.

Ion Chromatography: Dionex DX-120 and DX-500 ion chromatography systems were used for this work. The system includes GP50 Gradient Pump, CD20 Conductivity Detector and AS40 Autosampler with 5-mL vials. The system was linked to A PeakNet Chromatography Workstation.

The eluent was 3.5 mM sodium carbonate/1.0 mM sodium bicarbonate (IonPac AS4A). The sodium and potassium salts of the anions ACS grade, were used for the preparing of the standards. Deionized water (with 18 MΩ-cm resistance) were used for dilution and preparation of standard solution.

IonPac AG4A-SC, 4 × 50 mm column was used for the analysis of DW samples. The flow rate of the eluent was 2.0 mL/min. Sample aliquots of 50 µL were injected and the detection was done with suppressed conductivity. The vial caps in the AS40 Automated Sampler contain a 20-µm filter, so no additional filtration was used in conjunction with this mode of sample introduction.

Gas Chromatography for THMs: A 10 mL aliquot of each water sample or standard was placed in 20 mL headspace autosampler vials which contained 2.5 g of NaCl to force the THMs gas phase where they are collected by the SPME fiber. The vials were incubated at 65°C for 30 minutes and agitated at 100 rpm (10 second duration, every 60 seconds). Three minutes were necessary for the desorption at 260°C. The analysis were performed on Agilent 6890 Gas Chromatograph with electron capture detector using heating program starting from 60°C (2 minute hold), and heating up at 30°C/minute to 250°C (10 minute hold).

RESULTS

Table 2 shows the pH, electrical conductivity (EC), total dissolved solids (TDS) and hardness of 15 residence samples and 12 water samples taken directly from the water production stations within Baghdad. The pH values fall between 7.05 and 7.84 and the average value was 7.67. The hardness values fall between 280 and 440 mg/L and the average is 339.6 mg/L. The TDS values fall between 486 and 860 mg/L and the average is 546.3 mg/L. The EC values fall between 673 and 1200 mg/L and the average is 827.0 mg/L.

Table 3 shows the concentration values of the major anions: SO_4^{2-}, Cl^- , NO_3^-, and F^-. The sulphate concentration values fall between 280 and 440 mg/L and the average is 230.1 mg/L. The chloride concentration values fall between 50 and 120 mg/L and the average is 67.7 mg/L.

TABLE 2. PHYSIOCHEMICAL CHARACTERISTICS OF TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW) FROM BAGHDAD

No.	Location	Total Hardness (mg/L)	TDS, mg/L (180) ^{o}C.	Conductivity µS/cm	Ph
1	Utaifiya, Q409	410	725	1007	7.84
2	Jihad, Q889	280	501	695	7.74
3	Zufaraniya, Q954	430	770	1070	7.73
4	Mamudiya, Q14 Ramdan	430	845	1173	7.71
5	Talbiya, Q 323	320	612	849	7.82
6	Mamudiya Q 17 july	440	864	1200	7.73
7	Kadhmiya, Q402	420	749	1041	7.77
8	Shaab, Q337	310	608	843	7.84
9	2n Amin, 741	300	588	815	7.83
10	Qarrada, Q905	420	753	1046	7.75
11	Qarrada, Q905	350	642	892	7.74
12	Qadsiya, Q602	270	512	709	7.88
13	Salhiya, Q 28 Niss	320	593	823	7.82
14	Falstin st, Q503	280	522	724	7.87
15	adr City, Q529	310	605	839	7.88
16	Dora Project (R)	320	492	681	7.05
17	Dora Project (T)	310	487	675	7.28
18	Whda Project (R)	310	486	673	7.51
19	Whda Project (T)	310	494	685	7.56
20	9 Apr Project (R)	320	508	704	7.69
21	9 Apr Project (T)	320	507	703	7.81
22	Qadsiya Project (R)	310	485	672	7.84
23	Qadsiya Project (T)	310	489	677	7.79
24	Wathba Project(R)	340	557	772	7.85
25	WathbaProject (T)	350	574	796	7.33
26	Project karama(R)	340	560	776	7.71
27	Karama Project (T)	340	571	791	7.60

TABLE 3. THE CONCENTRATION OF MAJOR ANIONS IN TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW)

No.	Location	Cl^- mg/ l	SO_4^{2-} mg/ l	F^- mg/ l	(SiO_2 mg/ l	Nitrite (mg/L)	Nitrate (mg/L)
	Iraqi Specification	250	250	1.0			
	WHO Specification	250	250	1.5			
	Europian Specification	250	500	1.5			
1	Utaifiya, Q409	250	250	1.0	-	<0.025	2
2	Jihad, Q889	250	250	1.5	-	<0.025	2
3	Zufaraniya, Q954	250	500	1.5	-	<0.025	2
4	Mamudiya, Q 14 Ramdn	74	338	< 0.5	5	<0.025	<1
5	Talbiya, Q 323	50	173	< 0.5	5	<0.025	2
6	Mamudiya Q 17 july	77	370	< 0.5	5	<0.025	<1
7	Kadhmiya, Q402	120	386	< 0.5	5	<0.025	<1
8	Shaab, Q337	65	251	< 0.5	4	<0.025	2
9	2n Amin, 741	120	397	< 0.5	5	<0.025	2
10	Qarrada, Q905	74	348	< 0.5	5	<0.025	2
11	Qarrada, Q905	65	225	< 0.5	4	<0.025	2
12	Qadsiya, Q602	61	200	< 0.5	5	<0.025	2
13	Salhiya, Q 28 Niss	72	336	< 0.5	5	<0.025	2
14	Falstin st, Q503	62	257	< 0.5	5	<0.025	2
15	Sadr City, Q529	49	162	< 0.5	4	<0.025	2
16	Dora Project (R)	55	215	< 0.5	4	1.49	4
17	Dora Project (T)	50	168	< 0.5	4	<0.025	6
18	Whda Project (R)	64	230	< 0.5	4	<0.025	6
19	Whda Project (T)	57	159	< 0.5	8	<0.025	6
20	9 Apr Project (R)	60	164	< 0.5	8	<0.025	6
21	9 Apr Project (T)	56	158	< 0.5	10	<0.025	6
22	Qadsiya Project (R)	61	162	< 0.5	8	<0.025	6
23	Qadsiya Project (T)	63	167	< 0.5	10	<0.025	6
24	Wathba Project(R)	64	175	< 0.5	8	<0.025	5
25	WathbaProject (T)	56	157	< 0.5	9	<0.025	6
26	Project karama(R)	60	162	< 0.5	8	<0.025	7
27	Karama Project (T)	72	200	< 0.5	13	<0.025	6

The results of the major cations, Ca^{2+}, Na^+, Mg^{2+} and K^+, concentrations are given in Table 4. The calcium concentration values fall between 61 and 118 mg/L and the average is 84.5 mg/L. The sodium concentration values fall between 20 and 32 mg/L and the average is 24.3 mg/L. The magnesium concentration values fall between 28 and 34 mg/L and the average is 31.1 mg/L. The results of some common metal ions like iron, aluminium, zinc, ammonium and lithium are given in Table 5.

TABLE 4. THE CONCENTRATION OF THE COMMON CATIONS IN TREATED (T0 AND RAW (R) WATER SAMPLES (DW) FROM BAGHDAD.

No.	Sample Location	Ca^{2+} mg/L	K^+ mg/L	Mg^{2+} mg/L	Na^+ mg/L	Total Cations mg/L
	Iraqi Specification	50	-	50	200	
	WHO Specification	-	-	-	-	
	Europian Specification	-	-	-	200	
1	Utaifiya, Q 409	111	1	33	26	171
2	Jihad, Q889	62	< 1	29	21	113
3	Zufaraniya, Q954	118	2	32	26	178
4	Mamudiya, Q 14 Ramdn	111	< 1	36	32	180
5	Talbiya, Q 323	68	1	35	26	148
6	Mamudiya Q 17 july	118	1	36	25	180
7	Kadhmiya, Q402	116	1	32	24	173
8	Shaab, Q337	67	2	34	26	129
9	2n Amin, 741	67	1	33	23	124
10	Qarrada, Q905	114	< 1	33	20	168
11	Qarrada, Q905	88	1	31	22	142
12	Qadsiya, Q602	61	< 1	29	21	112
13	Salhiya, Q 28 Nissan	80	1	30	25	136

TABLE 4 CONT. THE CONCENTRATION OF THE COMMON CATIONS IN TREATED (T0 AND RAW (R) WATER SAMPLES (DW) FROM BAGHDAD.

14	Falstin st, Q503	63	1	30	25	119
15	Adr City, Q529	67	2	35	32	136
16	Dora Project (R)	80	2	28	21	131
17	Dora Project (T)	78	2	28	21	129
18	Whda Project (R)	79	5	28	21	133
19	Whda Project (T)	79	1	28	32	140
20	9 Apr Project (R)	79	2	29	22	132
21	9 Apr Project (T)	78	<1	29	20	128
22	Qadsiya Project (R)	78	2	28	21	129
23	Qadsiya Project (T)	78	2	28	21	129
24	Wathba Project(R)	84	2	31	26	143
25	WathbaProject (T)	88	2	31	26	147
26	Project karama(R)	83	2	32	26	143
27	Karama Project (T)	86	2	31	26	145

TABLE 5. THE CONCENTRATIONS OF IRON, ALUMINUM, LITHIUM, ZINC AND AMMONIUM IN TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW).

No.	Location	Fe µg/L	Al mg/L	Zn, µg/L	NH_4, mg/L	Li µg/L
	Iraqi Specification	300	0.2	3000	<0.1	-
	WHO Specification	-	0.2	-	<0.1	-
	Europian Specification	200	0.2	-	<0.1	-
1	Utaifiya, Q409	29	0.15	320	<0.1	< 1
2	Jihad, Q889	76	0.18	84	<0.1	< 1
3	Zufaraniya, Q954	< 20	0.13	77	<0.1	< 1
4	Mamudia, Q 14 Ramdn	29	0.06	427	<0.1	< 1
5	Talbiya, Q 323	< 20	0.14	71	<0.1	< 1
6	Mamudiya Q 17 july	< 20	0.07	62	<0.1	< 1
7	Kadhmiya, Q402	< 20	0.16	39	<0.1	< 1
8	Shaab, Q337	< 20	0.14	< 20	<0.1	< 1
9	2n Amin, 741	47	0.18	26	<0.1	< 1
10	Qarrada, Q905	52	0.11	280	<0.1	< 1
11	Qarrada, Q905	59	0.08	963	<0.1	< 1
12	Qadsiya, Q602	23	0.13	123	<0.1	< 1
13	Salhiya, Q 28 Niss	< 20	0.12	41	<0.1	< 1
14	Falstin st, Q503	42	0.15	71	<0.1	< 1
15	adr City, Q529	< 20	0.14	28	<0.1	< 1
16	Dora Project (R)	34	0.067	40	<0.1	< 1
17	Dora Project (T)	< 20	0.14	< 20	<0.1	< 1
18	Whda Project (R)	233	0.33	< 20	<0.1	< 1
19	Whda Project (T)	32	0.17	< 20	<0.1	< 1
20	9 Apr Project (R)	251	0.32	< 20	<0.1	< 1
21	9 Apr Project (T)	< 20	0.12	< 20	<0.1	< 1
22	Qadsiya Project (R)	125	0.18	< 20	<0.1	< 1
23	Qadsiya Project (T)	31	0.14	< 20	<0.1	< 1
24	Wathba Project(R)	624	0.77	< 20	<0.1	< 1
25	WathbaProject (T)	< 20	0.07	< 20		< 1
26	Project karama(R)	595	0.73	< 20		< 1
27	Karama Project (T)	< 20	0.10	< 20		< 1

Table 6 shows the concentration values of trace and heavy metals in the DW and raw water samples. The concentration levels of trihalomethanes in the DW samples are listed in Table 7.

DISCUSSION

The pH values: The pH values of the water samples from the uptake stations (Prior to treatment) were between 7.05 – 7.85 for April 2006. For DW samples the pH values were in the range 7-28 -7.81 for April 2005. For the network the results indicated pH values of 7.74 to 7.88 for November 2005 and 7.51 – 7.96 for DW samples of June 2005. All the results are within the acceptable limits (6.5 – 8.5). However the WHO regulations do not include limits for the pH values for drinking water. European standard includes a range of 6.5 – 9.5 for the pH of DW.

TABLE 6. THE CONCENTRATION OF TRACE METALS IN TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW)

No.	Location	Pb µg/L	B mg/L	Ba mg/L	As µg/L	Cd µg/L	Cu µg/L	Ni µg/L	Cr µg/L	Mn µg/L
	Iraqi Spec.	10	-	0.7	10	3	1000	20	50	100
	WHO Spec.	10	0.003	0.3	10	5	2	20	50	40
	Europian Spec.	10	0.001	0.7	10	3	1	20	50	50
1	Utaifiya, Q409	< 20	0.11	< 0.1	< 10	< 1	< 5	< 20	< 5	1
2	Jihad, Q889	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	3
3	Zufaraniya, Q954	< 20	0.11	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
4	Mamudiya, Q 14 Ramdn	< 20	0.21	< 0.1	< 10	< 1	< 5	< 20	< 5	1
5	Talbiya, Q 323	< 20	0.12	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
6	Mamudiya Q 17 july	< 20	0.23	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
7	Kadhmiya, Q402	< 20	0.11	< 0.1	< 10	< 1	< 5	< 20	< 5	2
8	Shaab, Q337	< 20	0.12	< 0.1	< 10	< 1	< 5	< 20	< 5	2
9	2n Amin, 741	< 20	0.12	< 0.1	< 10	< 1	< 5	< 20	< 5	1
10	Qarrada, Q905	< 20	0.12	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
11	Qarrada, Q905	< 20	0.16	< 0.1	< 10	< 1	< 5	< 20	< 5	< 10
12	Qadsiya, Q602	< 20	0.10	< 0.1	< 10	< 1	< 5	< 20	< 5	2
13	Salhiya, Q 28 Niss	< 20	0.11	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
14	Falstin st, Q503	< 20	0.11	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
15	adr City, Q529	< 20	0.12	< 0.1	< 10	< 1	< 5	< 20	< 5	< 1
16	Dora Project (R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	3
17	Dora Project (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	<1
18	Whda Project (R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	5
19	Whda Project (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	1
20	9 Apr Project (R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	5
21	9 Apr Project (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	<1
22	Qadsiya Project (R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	2
23	Qadsiya Project (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	<1
24	Wathba Project(R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	10
25	WathbaProject (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	<1
26	Karama Project (R)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	9
27	Karama Project (T)	< 20	< 0.1	< 0.1	< 10	< 1	< 5	< 20	< 5	<1

TABLE 7. THE CONCENTRATION OF TRIHALOMETHANES IN TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW).

No.	Location	Chloroform µg/ l	Bromo form µg/ l	Chloro dibromo methane µg/ l	Dichloro bromo methane µg/ l	Total trihalo methanes µg/ l
1	Utaifiya, Q409	7	19	30	16	75
2	Jihad, Q889	21	13	31	25	90
3	Zufaraniya, Q954	<1	<1	<1	<1	<1
4	Mamudiya,Q-Ram. 14	<1	<1	2	2	3
5	Talbiya, Q 323	3	23	21	8	55
6	Mamudiya-Q-Jul 17	<1	<1	<1	<1	<1
7	Kadhmiya, Q402	14	14	32	22	82
8	Shaab, Q337	14	19	34	22	89
9	2n Amin, 741	22	15	34	26	97
10	Qarrada, Q905	4	1	3	2	10
11	Qarrada, Q905	11	11	24	16	62
12	Qadsiya, Q602	16	13	30	22	81
13	Salhiya, Q 28 Niss	10	15	28	16	69
14	Falstin st, Q503	17	13	32	24	86
15	adr City, Q529	31	9	25	28	93
16	Dora Project (R)	<1	<1	<1	<1	<1
17	Dora Project (T)	44	6	34	32	116
18	Whda Project (R)	<1	<1	<1	<1	<1
19	Whda Project (T)	26	5	29	26	86

TABLE 7 CONT. THE CONCENTRATION OF TRIHALOMETHANES IN TREATED (T) AND UNTREATED (R) WATER SAMPLES (DW).

20	9 Apr Project (R)	<1	<1	<1	<1	<1
21	9 Apr Project (T)	9	11	30	18	68
22	Qadsiya Project (R)	<1	<1	<1	<1	<1
23	Qadsiya Project (T)	46	5	34	31	116
24	Wathba Project(R)	<1	<1	<1	<1	<1
25	WathbaProject (T)	20	10	39	28	97
26	Project karama(R)	<1	<1	<1	<1	<1
27	Karama Project (T)	14	14	42	25	95

Water hardness: From our experience, the water hardness of the Baghdad aqueduct is around 30 °FH (French Degree – 1°FH is = 10 ppm of calcium carbonate equivalent dissolved in water). As for the samples analysed last December, the water hardness is waving between 30 and 45 °FH. In theory this parameter should be more homogeneous but it is not influencing the properties of the drinking water. The only effect is on the cleaning performances during washing.

It is interesting that the hardness values for water samples taken in Turkey which is located upstream of Tigris River ranges between 50 – 300 mg/L (Soylak *et al.,* 2002). When hardness was correlated with other parameters like calcium concentration a perfect correlation was obtained as shown in Fig. 2. Although magnesium compounds are essential participant in the total hardness its correlation coefficient was far less than that of calcium with hardness. The fact that calcium in most of the samples analysed was the major cation attributes for the excellent correlation of the total cations with hardness as in Fig. 3

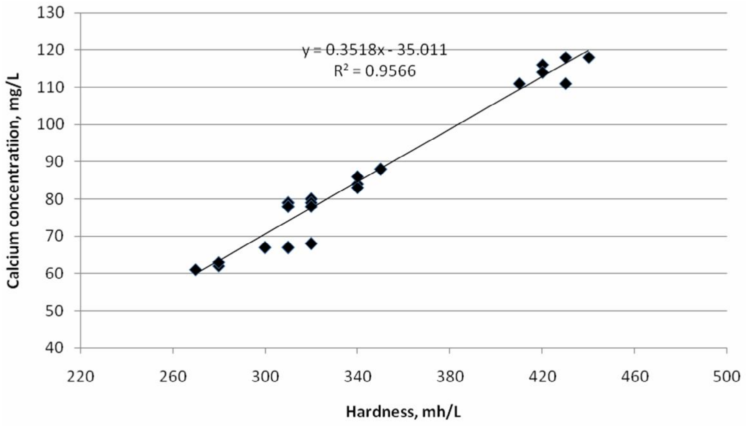

FIG. 2. CORRELATION OF HARDNESS WITH CALCIUM CONCENTRATION.

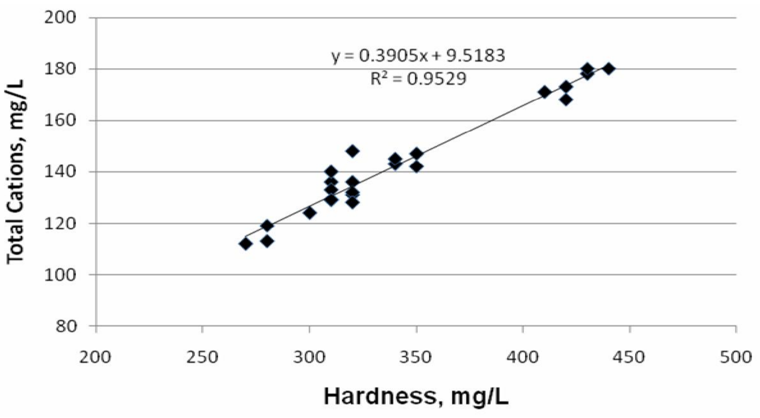

FIG. 3. CORRELATION OF HARDNESS WITH TOTAL MAJOR CATIONS.

Electrical Conductivity (EC): The conductivity and TDS values fluctuated in the samples, being particularly high when sulphates and chlorides are present at high concentration. This could be due to possible chemical contamination during the water treatment directly in the aqueduct plant. The results of EC were correlated with TDS values for the analysed samples and the correlation coefficient was unity. Meanwhile, Fig. 4 shows reasonable correlation could be obtained with total major cations concentrations (0.81). With hardness values Fig. 5 shows that the correlation of EC values is reasonable (0.82).

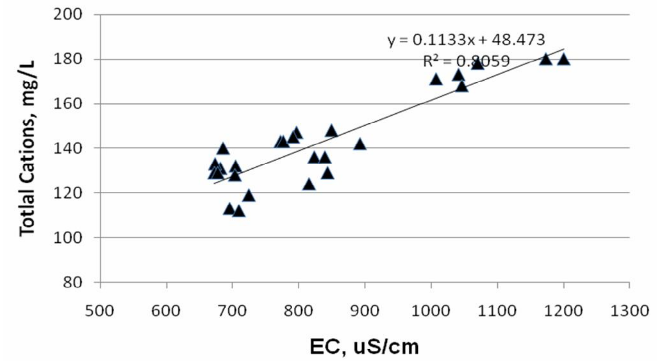

FIG. 4. CORRELATION OF EC VALUES WITH THE TOTAL MAJOR CATION CONCENTRATIONS.

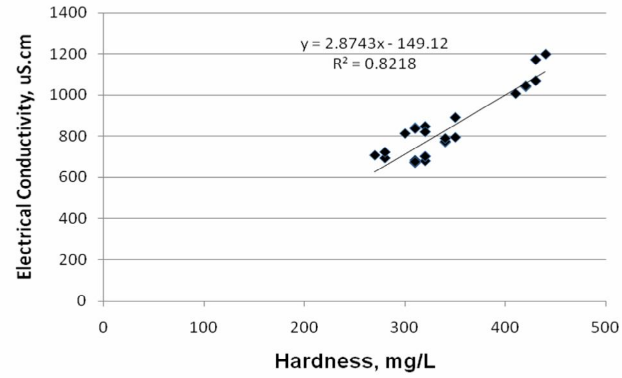

FIG. 5. CORRELATION OF EC VALUES WITH THE HARDNESS VALUES OF DW SAMPLES.

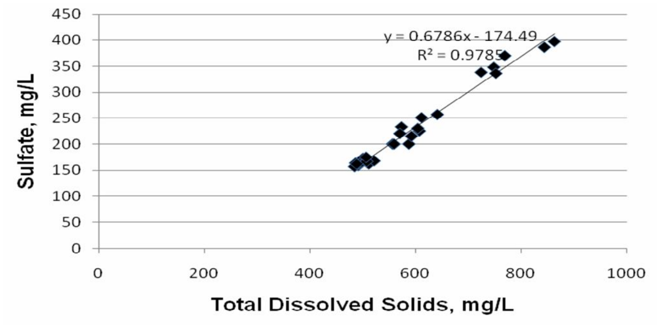

FIG. 6. CORRELATION OF SULFATE CONCENTRATION WITH TDS VALUES OF DW SAMPLES.

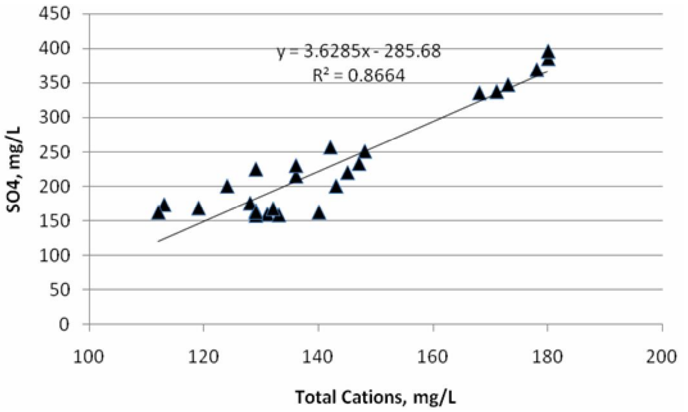

FIG. 7. CORRELATION OF SULFATE CONCENTRATIONS WITH TOTAL CATION CONCENTRATIONS OF DW SAMPLES.

The EC measurement of the samples indicated that the raw water and even after the treatment is characterized by relatively high and fluctuating EC values. They all fall between 600 µS/cm and 1200 µS/cm. The fluctuation is related to the season at which the sampling was made. The Iraqi standard does not include limits for the EC values of DW. Meanwhile, the WHO and the European standards recommended value of EC is 250 µS/cm. This matter needs to be studied to correlate the EC values with human health and to manage for the introduction of EC limits within the Iraqi Standard. The increase in EC is related to the increase in chloride and sulfate ions.

With the exception of zinc, all residence DW samples exhibited metal ion concentrations that are low or within the accepted levels. However, the raw water samples showed relatively higher Fe (233-624 µg/L) and Al (0.32 – 0.77 µg/L) concentrations than the DW sample from the corresponding stations or the residence DW samples. For zinc there were four residence DW samples that have distinct high levels (280-963 µg/L) in comparison with the rest of the samples. These four locations were considered among the oldest neighbourhoods in Baghdad which is indicative of the effect of the old construction on the results. Even though, the zinc concentration in all of the analysed samples was within the acceptable values.

Sulphate: Sulphate appears as the predominant anion among the whole anions analysed and thus, it give excellent correlation coefficients with the main parameters of water quality, being 0.98 with TDS values (Fig. 6) and 0.87 with total cations (Fig. 7).

Looking at the micro elements detected with the analyses, we can imagine that the main flocculation of the raw water has been carried out with aluminium sulphate. The relatively high level of residual aluminium ions found should confirm this hypothesis. Probably, the raw materials have been dosed spot and not with a continuous plant. This could be the reason why a fluctuating concentration of certain elements has been found.

$Al_2(SO_4)_3 + 3\ Ca(OH)_3 \rightarrow 2\ Al(OH)_3 + 3CaSO_4$ ...(1)
$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2$ ...(2)

Reduction of sulphates, paying attention to the dosage of flocculants, playing with the pH and precipitating them with calcium hydroxide will reduce the conductivity and dry residue of the drinking water.

It is worthwhile to note that natural DW quality in some communities in Ghana, the sulphate levels do not exceed 8.02 mg/L (Akoto & Adiyiah, 2007. People that are not used to drinking water with high levels of sulphate can experience dehydration and diarrhoea. Babies are more sensitive to sulphate than adults. As a safety measure, water with a sulphate level exceeding 400 ppm should not be used in the preparation of baby food (WHO directives). Older children and adults become used to high sulphate levels after a few days. In any case, water with high sulphates should be avoided for the rehydration of people with diarrhoea.

To confirm this hypothesis, it is necessary to carry out some checks on the raw water. Only these analyses will confirm the real origin of sulphates. Relatively high level of Magnesium, if compared with the Calcium content, should maintain the sulphate in solution. This is the reason why the addition of Calcium Hydroxide should help to remove the excess of sulphates. Clearly the addition of this chemical will reduce the efficiency of the plant. EU standards, in 1998, suggested a maximum of 250 mg/l of sulphates in water intended for human consumption.

Chlorides: In all the samples analysed, chlorides did not exceed the maximum limit. The EU max limit is 250 mg/L. The chloride values on all the samples were in the range of 50 – 120 mg/L. The real origin of the chlorides exceeding the 50 mg/L in this batch of samples is not fully understood. They waved from 50 to 120 mg/L. This fluctuation is quite high if reported to the same origin of the raw water. As for sulphates, they should arrive from a contamination point just before the treatment plant or from the treatment process itself. In theory, chlorides could be originated from the chlorination process; in particular if the break point of the chlorine is very high but, in this case, the dosage of sodium hypochlorite should be very high (about 50 mg/L) to destroy all the organic matter present in the raw water. This can justify an extra 70 mg/L of chlorides.

The use of degraded hypochlorite raw material used for water chlorination may account for a high concentration of chloride. For each mole of Hypochlorite a mole of sodium chloride is produced in the reaction. In general, sunlight and high temperature are the main causes of the Hypochlorite degradation. As by-product of the hypo degradation the formation of chloride occurs. See the reaction

$2NaOCl \rightarrow 2NaCl + O_2$ ...(3)

In conclusion, degradation of the hypochlorite is the main cause of the chloride formation in the bleach used for the water treatment. Clearly, with a lower level of available chlorine in the bleach, a higher dosage is required to disinfect the water. As a consequence of this situation a very high dosage of chlorine may occur in the water treatment plant. As alternative to the sodium hypochlorite, a more stable but difficult to handle Calcium Hypochlorite could be used.

Boron: Boron contamination of water is impacting the male reproduction system of mammals (human included). For this reason, the EU legislation is now more restrictive. The maximum level allowed is 1 mg/L (WHO, 1998a). The origin of this element could be geogenic or from domestic detergents. However, boron compounds are rarely used in the production of detergents in Iraq. The boron content in nearly all the residence DW samples was higher than 0.1 mg/L which is only slightly higher than those of raw water samples. However, boron is widely distributed in surface water and groundwater. The average surface water concentration is about 0.1 mg/L. In ground water boron concentrations in ground water can be as high as 10 mg/L in areas to the west of Euphrates River (Al-Dabbas, 2006). Besides, concentrations up to 0.4 mg/L have been found in most drinking water samples (Kwon, *et al*., 2005).

In this case boron could be only of natural origin. To exclude the sewage contamination two or three samples of the river water should be picked up to the north of the river; possibly outside the town. These samples should be compared with the samples picked up on the river just before the treatment plant.

Diaconu *et al.,* (2008) reported boron concentrations levels of 0.02 – 1.55 mg/L in Romanian DW, which is comparatively higher than the results of Baghdad area DW.

Nitrogen compounds: No detectable ammonia and nitrite could be found in these DW samples. Generally they change their form when hypochlorite is added (Fair, et al. 1948. Ammonia becomes Chloroamine and Nitrite becomes Nitrate (Lahoutifard *et al.,* 2003).

$NH_3 + HOCl \rightarrow H_2O + NH_2Cl$ (monochloramine) ... (4)
$NH_2Cl + HOCl \rightarrow H_2O + NHCl_2$ (dichloramine) ... (5)
$NHCl_2 + HOCl \rightarrow H_2O + NCl_3$ (trichloramine) ...(6)

In any case, 3 of the samples received were not chlorinated (Al Zoufrania, Al Mahmodia and Mahmodia 17th July). In all these samples, Ammonia and Nitrite are lower than the detectable limit. This means that, in general, we should not have a sewage contamination of the drinking water. The level of Nitrate is lower than that noticed in 2004 (Barbooti *et al.,* 2005. This is probably due to the dry season with limited raining. Consequently, no surface water is available to wash away organic compounds in the river incoming water and all the Nitrogen available is fixed by the water plant present in the stream (Patriquin & Knowles, 1972.

Iron: The various levels of iron in different samples of water could not be explained. The original pH of the river water is between 7.5 and 8.0. Corrosion of the pipes could partly explain this observation, because flocculation is seldom performed in Iraq by ferric chloride ($FeCl_3$). In any case, the relatively high levels of iron are not impacting the quality of the drinking water except the taste and the red residues on basins, showers, toilets, etc. High level of zinc on four samples can be explained with the probable corrosion of the pipelines. Zinc is not impacting the quality of drinking water.

Aluminum: The concentration of Aluminum in the analysed DW samples was in the range of 0.06 - 0.77 mg/L. Aluminum levels in drinking-water vary according to the levels found in the source water and whether aluminum coagulants are used during water treatment (WHO, 1998b). In Germany, levels of aluminum in public water supplies averaged 0.01 mg/L in the western region, whereas levels in 2.7% of public supplies in the eastern region exceeded 0.2 mg/L. In a 1993–1994 survey of public water supplies in Ontario, Canada, 75% of all average levels were less than 0.1 mg/L, with a range of 0.04–0.85 mg/L. In a large monitoring program in 1991 in the United Kingdom, concentrations in 553 samples (0.7%) exceeded 0.2 mg/L (Wilhelm & Adel, 1995).

The fluoride concentration levels in all the analyzed DW samples were lower than the permissible levels. However, there exist some implications for the combined effects of aluminum with fluoride even at such low levels (Verner *et al.,* 1998).

As for Sulphates, aluminium can be easily removed with Calcium Hydroxide. Detectable Aluminium presence in water at pH between 7.5 and 8.0 can be explained only with the flocculation process carried out with Aluminium Sulphate. Details are available in the Sulphate sections.

As for Sulphates, Aluminium can be easily removed with Calcium Hydroxide.

$$Al_2(SO_4)_3 + 3\,Ca(OH)_3 \rightarrow 2\,Al(OH)_3 + 3CaSO_4 \quad ...\ (7)$$

The products of this reaction ($Al(OH)_3$ and $CaSO_4$ are insoluble in water. However, high water hardness should help this process and the addition of Calcium Hydroxide should not be necessary. The reaction of the calcium salts of water hardness with aluminium sulphate is reported below:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2 \quad ..(8)$$

Trihalomethanes: The THM's formation in DW is a direct consequence of the chlorination process of the water with hypochlorite. Humic acids present in the ground water reacts with the chlorine forming these compounds. The maximum limit allowed by the EU legislation is of 30 ppb. These compounds are considered hepatotoxic and chloroform carcinogenic. The amount of total THMs allowed in drinking water is regulated by the USEPA, which has a set total THM annual average safe limit of 80 µg/L in drinking water (Tanglewood Water System, 2007).

Some studies linked THMs (Bromodichloromethane (BDCM), to possible stillbirths, miscarriages and birth defects, and bladder and rectal cancers. The Virginian Pilot reported that Chlorine mixes with organic materials, like algae and leaf particles, which includes chloroform and BDCM. In 1998, THM was suspected as a carcinogen and possible cause of miscarriages in Florida (Madabhushi, 1999). Around that time, a new water treatment plant was being upgraded and reports say the levels of THM were higher than normal for about nine months (Singer, 2006).

Except the sample picked from Al Zaafrania and the two samples picked from Al Mahmodia, all the water analysed contain THM's. This means that the water has been chlorinated properly to kill bacteria. Unfortunately the residual THM's present are over the EU limits. In any case, it must be noticed that WHO stated that it is better to have these contaminants in drinking water instead of bacteria. There are at least two techniques available to maintain these contaminants under the maximum limit. The first is the flocculation process and the second is the use of activated carbon. If necessary, both techniques can be used in series: flocculation first followed by filtration through activated carbon.

Chlorine usually provides residual disinfection throughout the public-water distribution system. Ozone provides a residual disinfection for a limited time. However, bottled water may be in distribution for several weeks and storage conditions, especially temperature, may adversely affect quality. In terms of bacterial content, it is questionable as to whether bottled water is better than most municipal tap water (Kendall, 1992).

CONCLUSIONS

Generally, the samples of water analysed may be considered of good quality. Only 3 samples do not contain THM's. As we were sure of the chlorination of this water, the first consequence could be a microbiological contamination of this water with the related problems.

Organic contents of DW indicated the presence of organic materials. However, the flocculation with ferric chloride is considered better than Aluminium sulphate for the removal of humic acids. Iron is able to bind these organic compounds and remove them from the water. The relatively expensive adsorption on activated carbon is the most efficient process to remove these contaminants. It must be used after flocculation and the oxidation phase. However, it will completely remove the added chlorine which means that the DW must be chlorinated again with a low level of chlorine to maintain it free from bacteria in the pipelines during the distribution. The advantage of activated carbon is the ability to remove bad taste and smell from the water improving its organoleptic characteristics. Waterline plant in use at the Italian Red Cross hospital in the Medical City Centre, Baghdad, applies this type of process.

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