Quality assessment of physico-chemical parameters for various bottled waters marketed in Baghdad City, Iraq; An environmental approach

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Abstract

Twenty five domestic bottled water brands of available commercially sold in Baghdad Provence (Iraq) were collected from local markets. Recorded results were compared with the Iraqi Standards Institution, standards of quality and standards of identity as well as various international water standards for bottled waters. Results showed widespread in the characteristics of investigated bottled waters, yet the majority met the bottled water standards for physico-chemical parameters. Generated Piper diagrams revealed that the majority of investigated waters are of calcium–magnesium sulphate type; some brands were rich in sodium–potassium bicarbonate, and few were of the mixed type. Application of the Piper diagram shows that the majority of the tested bottled water brands originated from limestone aquifer, with the minor from limestone and evaporite origin or gypcrete sediments.

Comparison of the study results with reported label values indicated good agreement with stated pH values as well as Mg^{+2}, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, $HCO3^{-}$, Cl^{-}, and $SO4^{-2}$. The classification of the tested bottled waters according to TDS contents is ranging from very low to low mineral concentrations. Based on the classification criteria of the total hardness, most of the examined water brands considered to have soft to moderately hard waters.

Water quality for physico-chemical parameters were estimated to ascertain compliance with recommended standards by World Health Organization (WHO, 2008) and Iraqi Standards (IQS, 2009) for drinking water. The recorded results are coincides with the WHO and IQS standards for drinking water, which indicates the potability of the bottled waters and hence, could be consumed without any possible health problems.

Keywords Bottled water, Water quality, Piper diagrams, Baghdad-Iraq

1. INTRODUCTION

Water is the basic element for live and survive in the earth planet (Petraccia et al., 2006, Alemdar et al., 2009). Safe and good quality drinking water is the fundamental for good human health (Karavoltsos et al., 2008, Krachler and Shotyk 2009). Good quality is of basic importance for human physiology and the human lives depend basically on availability. An average human body weight is ranging from 53 kg - 63 kg, requires about 3 liters of water in the liquids and food daily to keep healthy (Wardlow *et al*., 2004).

The consumption of the bottled has been growing steadily worldwide during the last three decades and is regarded as the fastest growing and most dynamic sector of all the food and beverage industries. The worldwide consumption of bottled waters was estimated to escalate from 130,956 million liters in 2002 to 188,777 million liters in 2007; thus, the average annual global consumption rate calculates to 28.8 L per capita for the year 2007

(Beverage Marketing Corporation 2008). The average European Union consumption of bottled water was 104.2 L per capita, whereas the US bottled water market per capita consumption was 110.9 L (European Federation of Bottled Water 2006; Beverage Marketing Corporation 2008). *Bottled water* is define as water that is intended for human consumption and is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents. Fluoride may be optionally added within established quality standards (FDA 2008).

The Beverage Marketing Corporation is reporting that sales of bottled water grew nearly 7 % between 2011 and 2012, with consumption reaching a staggering 30.8 gallons / person (Table 1). The world's bottled water industry recorded yearly growth rate of 4% in 2010 to exceed $99 billion. The market is expected to expand by more than 27% in the five-year period ending 2015 to generate more than $126 billion in revenue. In 2010, the market had a volume in excess of 152 billion liter, forecast to reach close to 183 billion liters in 2010, representing 20% increasing in five years (Fig 1) (Table 1) (Beverage Marketing Corporation, 2012).

The dramatic increase in bottled water consumption has been mainly attributed to (a) consumers' concern over securing safe and accessible drinking water; (b) consumers' objection to offensive tastes and odors from municipal water supplies as well as to fluoride, chlorine, and other additives; (c) consumers' awareness in regarding bottled water as a healthy alternative to other beverages to improve diet and health; (d) consumers' belief that natural mineral waters have beneficial medicinal and therapeutic effects; (e) consumers' perception that bottled water consumption confers higher social status; and finally, (f) manufacturers' successful and efficient promotion of bottled water as pure and impeccably clean water, ideal for infants, elderly, and immune-suppressed individuals. In recent years, the popularity of bottled water can be gauged by the number of brands (over 5,000) produced worldwide (Güler 2007). However, bottled water is not necessarily safer than tap water, and over the years, concerns have been raised about the quality of bottled water marketed worldwide. Literature revealed that the levels of some water constituents in bottled water may be in violation of action levels for various parameters (Karamanis et al. 2007).

Organization (WHO)/Food and Agriculture Organization, regulates the bottled and mineral waters (CAC 2001). Other countries have defined local acceptable standards typically in harmonization with broader regulatory agencies such as WHO, USEPA, and the Council of European Economic Community Directive. Iraq is not peripheral to the bottled water industry; in fact, the per capita consumption of bottled water has been on a sharp rise in the last 10 years. However, despite its abundance, good quality drinking water is not readily available to man (Onweluzo and Akuagbazie, 2010).

Thirty-six years ago, this industry didn't exist. Americans drank less than two per year, and almost all of that was in the form of water from big office coolers. Figure 1 shows the dramatic exponential growth in bottled water sales over this period. There was a slight downturn in 2008 and 2009, attributed in part to a growing public campaign against bottled water and in part to the severe recession (Gleick, 2013).

Drinking water plays a major role in the intake of some of valuable and toxic trace elements in human's body (Nkono and Asubiojo, 1997; Turk and Alp, 2010). The chemical quality of drinking water during recent years has deteriorated considerably due to the presence of toxic elements, which even in traces are a serious cause of health hazard (Ikem *et al.,* 2002). Besides the geochemical strata of groundwater sources, the problem is mostly traceable to the indiscriminate discharge of industrial effluents, leading to the chemical contamination of natural water bodies (Ikem *et al.,* 2002).

Because of the high risk and health hazards associated with intake of contaminated tap water, the consumption of bottled water is becoming popular worldwide, particularly due to ready availability at reasonable cost, better taste, and the presence of traces of impurities. Bottled water not only serves the drinking purpose, it has also found wide usage in infant formula preparations, reconstitution of various food products, skincare formulations, and for filling humidifiers (Warburton, 1993).

The rapid and untracked increase in the bottled water market prompts concerns about the quality of bottled water marketed in Iraq. As numerous studies were conducted to assess bottled water quality in neighboring countries, sporadic studies were conducted on selected bottled water brands and for few parameters only (Alabdula'aly and Khan 1999; Al Fraij et al. 1999; Nsanze et al. 1999; Saleh et al. 2001; El-Fadel et al. 2003; Bataresh 2006; Karamanis et al. 2007; Baba et al. 2008).

This study aims at comprehensively investigating the physico-chemical quality of most available bottled water brands consumed in Baghdad city, along with the selected parameters are compared with prescribed Iraqi and World Health Organization drinking water standards.

2. MATERIALS AND METHODS

Twenty five (25) brands of bottled waters were purchased in duplicate polyethylene terephthalate (PET) containers, collected during summer 2013, from randomly selected grocery shops and supermarkets from Baghdad City-Iraq. Container sizes varied from 0.5 to 1.0 liter in volume. All these samples were stored at ambient conditions (23–25◦C) prior to complete the concerned analyses. The brands of bottled water list generalized information about the chemical composition on labels include; pH, TDS, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, $SO_4{}^{2-}$ and $HCO_3{}^-$ parameters, as well as expiry dates. To keep the brand names anonymous, bottled water samples were given numerical codes and this convention was used throughout the study.

The conducted analyses included physical and aggregate properties such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) and Total alkalinity; major nonmetallic inorganic constituents such as pH, chloride (Cl^-), sulphate ($SO4^{-2}$), and bicarbonate ($HCO3^-$); major elements include calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), and potassium (K^+).

The physicochemical parameters of the water samples were analyzed immediately after the collection. The conducted analysis included physical parameters (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Hardness (TH), were measured using the portable meter for pH, EC, TH and TDS. The major nonmetallic inorganic constituents include; (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, $SO_4{}^{2-}$ and $HCO_3{}^-$) were determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) technique, which were carried out in the ALS Laboratory in Spain. It is noteworthy to mention that all the analytical tests were performed in accordance to the *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 2005) and/or the USEPA accepted reference methods (Nelson 2003).

3. RESULTS AND DISCUSSION

3.1 Physico-chemical quality

The physico-chemical parameters of the analyzed Iraqi drinking bottled waters are summarized in Tables 3 and 4 for twenty five brands, together with corresponding guidelines of Iraqi Standards (2009) and the World Health Organization (2008) for drinking water.

The physical and aggregate properties of the tested waters range between 6.1 and 7.1 (mean = 6.5) for pH, 10 and 310 μS/cm at 25◦C (mean 187.2 μS/cm at 25◦C) for EC, 0.0 and 150.0 mg/L (mean =95 mg/L) for TDS, and 9.0 and 145.0 mg/L as CaCO3 (mean = 57.64 mg/L as CaCO3) for total hardness, 0.55 and 66.0 mg/L (mean = 44.44 mg/L) for TDS and 9 and 145 mg/L as $HCO3^{-}$ (mean = 57.36 mg/L) for total alkalinity.

The major ionic composition of tested bottled waters varies between 1 and 187 mg/L (mean = 24.5 mg/L) for Cl^{-}, 5 and 86.8 mg/L (mean = 31.94 mg/L) for $SO4^{-2}$, 0.2 and 10 (mean = 8.3 mg/L) for Ca^{+2}, 0.012 and 10 mg/L (mean = 5.77 mg/L) for Mg^{+2}, 0.06 and 2.11 mg/L (mean = 0.63 mg/L) for K^{+1} and 0.9 and 10 mg/L (mean = 7.55 mg/L) for Na^{+1}.

When compared to various national and international standards of quality for bottled waters (Table 2, 3), recorded concentrations are within acceptable ranges. However, such violations do not pose major health concerns, as EC is categorized as a secondary water standard by the USEPA, whereas EC in bottled waters are not regulated except by Iraqi Standards (IQS). The level specified by IQS to classify water as suitable for baby food and formula preparations.

When assessing the total mineralization of investigated bottled waters, the most frequently adopted parameter by the bottled water industry, the EC, which represents a function of the mineral content. According to the EC in the WHO (2008) mineral natural waters are categorized into very low mineral content, also termed as oligomineral waters (Feru 2004).

The analyzed water quality constituents show results lie within the acceptable limits of the respective guidelines, directives and the standard of Iraqi Standards (2009) and the World Health Organization (2008) for drinking water.

The chemical characteristics of the bottled water composition, on the basis of major ion concentrations, were also evaluated on a trilinear or Piper diagram (Fig 2) generated by the GW Chart software v. 1.19.0.0 (Winston 2000). When the concentrations are evaluated, it can be readily seen that the investigated bottled waters fall into three categories. First, water group of (17) brands that is relatively rich in calcium magnesium sulphate probably originating from limestone aquifers interbedded with little gypsum rocks. The second group of (5) brands rich in sodium potassium bicarbonate, probably originated in aquifer composed of minor evaporite with major carbonate rocks. While (3) brands contain mixed chemical compositions rich in calcium and sulfate (Fig 2).

3.2 Classification of tested bottled water

Different hydrochemical classification systems can be used to classify the water types. In the present study, the European Union (EU) mineral water directive (Vander Aa, 2003) was used to classify the water according to TDS and total hardness (Table 4, 5). The classification systems used to identify the chemical similarities and/or differences between the bottled water brands. The criteria for the chemical composition of mineral water according to the EU mineral water directives are given in Table (5). The criteria shows distinction based on TDS and further specification based on some characterizing cations and anions.

Table (5) shows the classification of the tested brands of the bottled water in accordance to the EU mineral water directive. For the case of brands 1B and 10B fall in the class "very low mineral concentration" (with TDS<50 mg/L), while the other brands fall in class "low mineral concentration" (with TDS between 50-500 mg/L).

The classification of the tested bottled water brands based on the total hardness according to the EU mineral water directive are shown in Table (5). Most of the brands with total hardness of 0-50 mg/L are considered as soft water; other brands with hardness between 50-100 mg/L is considered as moderately hard water. The Total hardness in water is caused by dissolved calcium and lesser extent magnesium (Mihayo and Mkoma, 2012).

3.3 EC and TDS

The chemical content of bottled water is a function of the rock composition of the source from which the water was originated and migrated. For example, similar types of rock may lead to give different types of mineral water. The chemical content depends on the availability of mineralizing agents, such as CO2 concentration, redox conditions and the type of adsorption complexes (Birke et al., 2010). Levels of EC and TDS in bottled water brands and their comparison to Iraqi Standards and WHO limit values are presented in Table 2. The ranges for these parameters were: 10-610 µS/cm for EC with a median of 187.2 µS/cm and 0-300 mg/L for TDS with a median of 95.2 mg/L. There is a variation between EC and TDS values of the bottled water brands; this depends on the origin of the water and the treatment or purification method applied during bottling process (Mihayo and Mkoma, 2012). The pH of all brands was around neutral, ranging from 6.1-7.1 with a median of 6.5; this may have been done in processing as recommended for drinking water.

Generally, the results show that the bottled water brands are quite different in characteristics. The observed variations in the chemical constituents might be resulting from the origins, residence time, atmospheric conditions and purification or treatment process employed by the manufacturers (Mihayo and Mkoma, 2012).

4. CONCLUSION AND RECOMMENDATION

Twenty five domestic bottled water brands were analyzed for various physico-chemical water parameters. Results showed a widespread in the characteristics of investigated bottled waters, yet the majority met the various national and international bottled water standards for physico-chemical parameters.

However, the physico-chemical quality of the studied bottled water brands was variable, possibly depends on many factors such as natural environment, source water composition and the type of treatment/purification technique(s) applied during the production. Additional changes in the water chemistries may also occur during storage and transportation, especially when the bottles are exposed to direct sunlight.

The chemical quality of bottled water depends on the source and chemical composition of the raw water. It also depends on the treatment technologies used by various manufacturers.

Generated Piper diagrams revealed that the majority of the investigated waters are of calcium–magnesium sulphate type, some brands were rich in sodium–potassium bicarbonate, and few were of the mixed type of calcium and sulfate. Comparison of the study results with reported label values indicated good agreement with stated pH values as well as Mg^{+2}, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, $HCO3^{-}$, Cl^{-}, and $SO4^{-2}$.

It is recommended that all marketed bottled waters be monitored for quality and identity and be licensed by concerned authorities to safeguard consumers' health.

In general, all elemental concentrations are within the acceptable limits of Iraqi Standards (2009) and the World Health Organization for drinking water (2008).

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Table 1. Global bottled market per capita consumption by leading countries from 2006 to 2011 (Beverage Marketing Corporation, 2012).

GLOBAL BOTTLED WATER MARKET per capita consumption by leading countries 2006 – 2011			
2011		*Gallons per capita*	
Rank	*Countries*	*2006*	*2011*
1	Mexico	50.5	65.5
2	Italy	53.6	49.9
3	Thailand	21.7	44.9
4	United Arab Emirates	31.6	43.2
5	Belgium-Luxembourg	38.3	38.3
6	France	37.5	36.3
7	Germany	34.1	36.0
8	Lebanon	31.0	32.8
9	Spain	20.1	29.3
10	Switzerland	29.0	29.4
11	United States	27.6	29.2
12	Hungary	23.0	28.7
13	Croatia	21.6	28.0
14	Slovenia	22.0	27.9
15	China, Hong Kong SAR	20.4	27.5
16	Qatar	22.6	27.3
17	Cyprus	27.1	26.9
18	Saudi Arabia	25.7	26.4
19	Austria	21.8	25.0
20	Portugal	24.3	23.9
	Global Average	7.2	8.8
Source: Beverage Marketing Corporation copyright© 2012 by beverage Marketing corporation			

Table 2. Physical and aggregate properties of investigated bottled water brands from Baghdad City-Iraq

Brand code	pH (at 25^{0}C)	EC (µS/cm at 25◦C)	TDS (mg/L)	Bicarbonate alkalinity (mg/L CaCO3)	Total hardness (mg/L CaCO3)
1B	7	10	0	15	0.55
2B	6.5	180	90	31	43.5
3B	6.5	120	50	35	38.7
4B	6.5	310	150	81	59.9
5B	6.1	290	140	18	10.9
6B	6.5	310	150	15	11.6
7B	6.1	180	80	79	65.23
8B	6.5	310	150	48	45.4
9B	6.6	140	70	42	41.23
10B	6.7	70	30	37	9.3
11B	6.5	180	90	46	45.13
12B	6.5	240	120	77	53.4
13B	6.5	110	50	42	38.4
14B	7.1	240	120	62	54.4
1S	6.7	160	80	95	65.3
2S	6.2	240	120	66	66
3S	6.7	180	90	106	61.9
4S	6.6	150	70	92	61
1D	6.7	190	90	121	49.24
2D	6.2	270	130	145	51.7
1KU	6.5	260	130	53	46.6
2KU	6.2	180	90	20	58.4
3KU	6.3	180	90	9	41.5
1K	6.5	180	90	84	47.6
1H	6.4	230	110	22	44.3
Range	6.1-7.1	10-310	0-150	9-145	0.55-66
Mean	6.5	187.2	95.2	57.64	44.44
IQS, 2009	**6.5-8.5**	**1000**	**---**	**---**	**500**
WHO, 2008	**6.5-9.5**	**600**	**2500**	**250**	**---**

Table 3. Concentrations (mg/L) of the major ions of investigated bottled water brands from Baghdad City-Iraq

Brand code	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	SO_4^{2-}	HCO_3^{-}
1B	0.2	0.012	4.3	0.06	1	5	15
2B	10	4.47	10	0.51	24.5	43.6	31
3B	10	3.34	9.3	0.36	10.4	26.5	35
4B	10	8.59	10	0.68	27.2	76.1	81
5B	3.1	0.837	10	1.18	104	11.3	18
6B	1.7	1.82	10	0.66	187	21	15
7B	10	9.79	10	0.8	28.2	79.4	79
8B	10	4.96	10	1.45	16.2	40.5	48
9B	10	3.95	8.4	0.38	10.2	34.6	42
10B	2.4	0.809	10	0.49	14.4	12.5	37
11B	10	4.92	10	0.68	17.8	34	46
12B	10	6.93	10	0.7	17.2	42.2	77
13B	10	3.25	10	0.41	9.83	17.3	42
14B	10	6.91	10	0.59	19.5	54.2	62
1S	10	9.78	3	0.22	1.81	5.28	95
2S	10	10	2.6	0.51	2.5	86.8	66
3S	10	9.06	2.2	0.21	1.98	6.08	106
4S	10	8.78	2.8	0.17	1.67	5	92
1D	10	5.9	0.9	0.16	1	5	121
2D	10	6.54	3.6	0.45	1.74	5	145
1KU	10	5.26	10	2.11	19	67.9	53
2KU	10	8.12	7.4	0.06	56	5	20
3KU	0.2	10	10	1.15	22	64.5	9
1K	10	5.5	4.3	0.82	7.12	22.8	84
1H	10	4.73	10	0.94	10.4	27	22
Range	0.2-10	0.012-10	0.9-10	0.06-2.11	1-187	5-86.8	9-145
Mean	8.30	5.77	7.55	0.63	24.5	31.94	57.36
IQS, 2009	150	100	200	--	350	--	--
WHO, 2008	--	--	200	---	250	250	

Table 4. The classification of the tested drinking bottled water based on EU mineral water directive (Mihayo and Mkoma, 2012).

Criterion	Water type
Mineral content (TDS) < 50 mg/L	Very low mineral concentration
TDS 50-500 mg/L	Low mineral concentration
TDS 500-1500 mg/L	Intermediate mineral concentration
TDS > 1500 mg/L	High mineral concentration
Sulphate > 200 mg/L	Containing sulphate
Chloride > 200 mg/L	Containing chloride
Calcium > 150 mg/L	Containing calcium
Magnesium > 50 mg/L	Containing magnesium
Bivalent iron > 1 mg/L	Containing magnesium

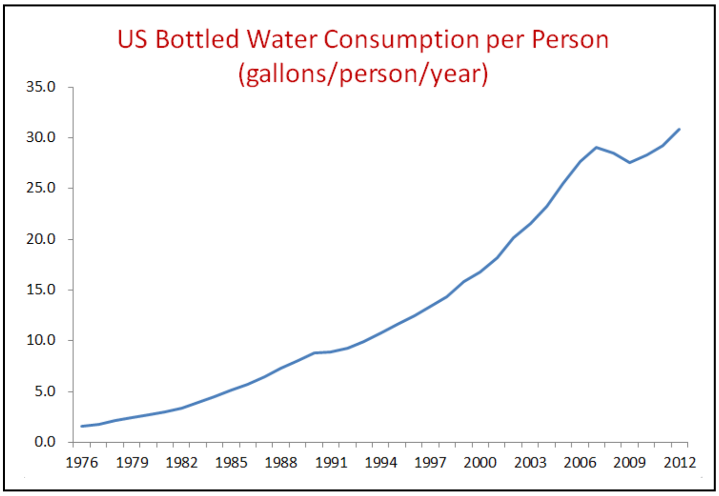

Figure 1. Bottled water sales per person in the United States, from 1976 to 2012. Data are from the Beverage Marketing Corporation (After Peter Geliek, 2012).

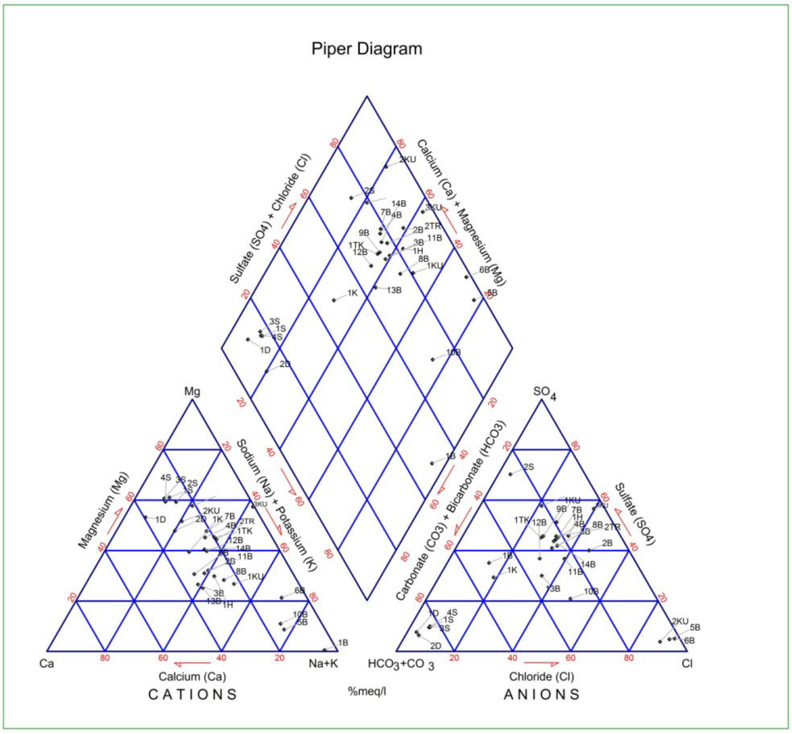

Figure 2. Application of Piper diagrams of investigated bottled waters.