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Original Article

Evaluation of the Physco-chemical Properties and Microbiological Content of Some Brands of Bottled Water in Baghdad, Iraq

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ABSTRACT
Due to the increased demand and consumption of bottled water in Iraq, there has been a growing concern about the quality of this product. Three replicates for each of 14 different bottled water brands were randomly collected from Baghdad region in summer 2012. Physical, chemical and microbial properties of all samples were evaluated which including pH, Electrical conductivity(EC), Total dissolved salts(TDS), Phosphate, Nitrate,Sulfates,Chlorides,Total hardness(TH), Calcium , Magnesium, Total coliforms (TC),Fecal streptococci (FS) and Clostridium spp.The results of the study showed the majority of the analyzed physical and chemicals properties were below their respective bottled drinking water standards for maximum admissible concentrations except Magnesium ion. In addition, of a total of 42 water samples was examined four samples were contaminated with total coliforms and three samples were contaminated with genus Clostridium spp.,with large numbers exceed the allowable limits for bottled drinking water. While not found fecal streptococci bacteria in other tests microbiological investigations. The study also showed there is no match in physical and chemical properties for large proportion of tested water with those characteristics mentioned in the labels on the bottles.
***Key words** : bottled water, drinking water, microbial properties,water standards*

INTRODUCTION

People buy bottled water for a variety of reasons, including fear of contamination, convenience, fashion, and taste or because they think it is safer than tap water [1,2]. As well as this preference for bottled water is due to the condition of tap water supplied to homes with an unacceptable taste and an unpleasant appearance in certain districts, which could be due to the taste of chlorinated tap water [3].Bottled water consumption has been steadily growing in the world for the past 30 years. It is the most dynamic sector of all the food and beverage industry. Consumption in the world increases by an average of 12% each year, in spite of its high price compared to tap water[4]. Recently, an increasingly worldwide concern about the quality of bottled water regarding their chemical contents has risen [5,6]. Mineral content of bottled water is one of the most important markers for water quality. Some minerals are required by our bodies for numerous biological and physiological processes that are necessary for the maintenance of health[7]. Also there is an increasing concern about the microbial quality of bottled water marketed worldwide. Several studies have documented the detection of coliforms and heterotrophic bacteria in bottled water in counts which far exceeded national and international standards set for potable water for human consumption [8].The aim of this study was to investigate the some physical, chemical and microbiological of some bottled water in Baghdad city. And the results obtained were compared with guidelines of drinking water recommended by the Iraqi and international standard specifications such as international bottled water association [9, 10].

MATERIALS AND METHODS

Forty two bottles representing 14 brands of bottled water were purchased randomly from different upper market stores in Baghdad city during the summer of 2012. All samples were in plastic containers with plastic screw caps. Table 1 presents the classification of the bottled waters in terms of brands, sources and volume. 3 samples of each brand were analyzed for selected parameters included: pH, Total dissolved salt sand Electrical conductivity were determined with portable Multimeter HANNA Model (HI 9811-5), while other examinations(Phosphate, Nitrate, Sulfates,Chlorides,Total hardness, Calcium and Magnesium) were done according to standard specifications presented by the American public health association [11]. Microbial examinations, which included total coliforms (TC), fecal streptococcus(FS) and gas producing clostridia conducted according to methods were mentioned in Forbes[12]and Garrity[13] by using the following identification tests (MacConkey broth, Eosin methylene blue,Azide dextrose broth,Differential Reinforced Clostridial Medium and Litmus milk). Standard deviation and correlation coefficient of parameters with each otherwere determined by using SPSS statistical package at significant probability ($P<0.05$) .

RESULTS AND DISCUSSION

The concentrations of major cations, anions, conductivity,pH, TD Sand bacterial counts in bottled water samples are shown in Table 1. The numbers shown are the average measurementsof three replicates for each of water brand. Also drinking water recommended standardsset by Iraqi standard specifications, United states food and drug administration, international bottled water association and the WHO are shown in Table 1.

Physical and chemical properties

The pH of the majority of the analyzed bottled waters were in the range of ranged from 6.2 to 7.8(Fig.1). Recommended pH values for drinking water according to (Table 1) are 6.5 to 8.5. These results suggest that all brands of studied bottled water are within the standard limits of Iraqi and world recommended values for bottled water. At pH values less than 6.5, water is corrosive and dissolves plumbing components [7]. High pH values (8.5 or more) can promote hardness scale precipitation and make chlorine disinfectants more effective. The results of the correlation coefficient indicated the presence of a significant positive correlation for pH with both of total hardness ($r=0.863$) and calcium ($r=0.840$).

Many salts are found dissolved in natural waters. The high concentration of dissolved solids(TDS) increases the density of water, reduces solubility of gases (like oxygen) so, the water is not suitable for drinking[14].

The quality of bottled water with respect to the tested parameters EC and TDS did not seem to be deteriorated. All the samples have the values of EC (59-597µS/cm)(Fig.2) and TDS (18–216mg/L) within legal recommendations. The highest value of TDS was observed in brand13(216 mg/L), while the lowest value was observed in brand 14(18mg/L)(Fig.3). The statistical analysis results for TDS showed significant positive correlations ($r=0.938$) with EC and ($r=0.719$) with sulfates and ($r=0.855$) with total hardness.

Sulfates salts(SO_4^{2-}) have been mostly soluble in water and impart hardness. Waters with about 500mg/ L sulfates are having a bitter taste and those with 1000mg/L or more sulfates may bring about intestinal disorders [15]. Experimental values show that all the samples are well within the ranges of the WHO and Iraqiof drinking water standardslimits(Fig.3). Sulfate is one of the least toxic anions and the major physiological effects resulting from the ingestion of large quantities of sulfate are catharsis, dehydration, and gastrointestinal irritation. However, because of the gastrointestinal effects resulting from the ingestion of drinking water containing high sulfate levels, it is recommended that health authorities be notified of sources of drinking water thatcontain sulfate concentrations in excess of 500 mg/L .

Phosphate (PO_4^{3-}) concentrations in the all samples ranged between none detected to 0.03 mg/L(Fig.4) . This makes phosphate concentrations too far from the maximum permissible limits by Iraqi and international guidelines. Compared with other nutrients, phosphate can be considered as least risk to human health.

Table 1: Average, standard deviation and the standard limits for the physical, chemical and microbiological properties in the bottled water in the Baghdad region

Bottled water brands	Company name	The producing country	The Size of bottle	pH	Conductivity (µS/cm)	TDS (Mg/L)	Sulfates (Mg/L)	Phosphate (Mg/L)	Nitrate (Mg/L)	Chloride (Mg as $CaCO_3$/L)	Total hardness (Mg/L)	Calcium (Mg/L)	Magnesium (Mg/L)	Total coliforms CFU/100ml	Fecal streptococci CFU/100ml	*Clostridium spp.* CFU/100ml
B1	Rawdatain	Kuwait	0.33 L	7.5 ± 0.06	573 ±22	214 ±6	137 ±10	ND	10.2 ±2.2	30 ±3	120 ±6	42 ±3.5	77 ±5	None	None	None
B2	Refresh	Kuwait	0.6 L	6.9 ±0.03	419 ±6	192 ±10	18.1 ±2	ND	1.2 ±0.5	73 ±5	95 ±10	17.5 ±2	77.5 ±4	None	None	None
B3	Karwan	Iraq	0.5 L	6.6 ±0.03	64 ±5	38 ±1	19 ±2	ND	3.1 ±1	5.6 ±1	15 ±3	2 ± 0.5	13 ±3	None	None	None
B4	Al_Waha	Iraq	0.5 L	6.8 ±0.05	426 ±9	130 ±7	56 ±4	ND	2.1 ±0.4	31.9 ±2	65 ±7	22.5 ±3	42.5 ±5	None	None	None
B5	Warda	Iraq	0.6 L	6.8 ±0.02	60.6 ±4	24 ±1	21.9 ±3	ND	1.1 ±0.3	12.4 ±2	20 ±3	1.5 ±1	18.5 ±2	400	None	None
B6	Sadir	Iraq	0.5 L	7.0 ±0.06	363 ±20	130 ±6	55.2 ±5	ND	2.2 0.2	10.6 ±2	120 ±9	20 ±3	80 ±10	None	None	None
B7	Yahya	Iraq	0.5 L	6.9 ±0.03	597 ±23	206 ±10	117 ±5	0.02 ±0.01	7 ±1	24.8 ±3	75 ±8	12.5 ±4	62.5 ±5	None	None	None
B8	Royal	Iraq	0.5 L	6.2 0.04	258 ±5	30 ±3	34.2 ±3	ND	1.2 ±1	39 ±4	20 ±2	5 ±1	15 ±	None	None	None
B9	Al-Hyat	Iraq	0.5 L	7.2 ±0.06	334 ±5	106 ±4	22.8 ±1	0.03 ±0.01	2.1 ±1	7.1 ±2	70 ±10	37.5 ±2	32.5 ±2	None	None	None
B10	Alssahab	Iraq	20 L	7.8 ±0.06	501 ±14	194 ±10	194 ±8	ND	12.4 ±2	28.4 ±3	135 ±12	35 ±3	100 ±2	400	None	100
B11	Sawa	Iraq	20 L	7.5 ±0.05	397 ±12	164 ±8	169 ±10	ND	13.7 ±2	21.3 ±2	102 ±7	45 ±1	57.5 ±10	None	None	None
B12	Al-Kaleej	Iraq	20 L	7.6 ±0.04	469 ±8	170 ±4	205 ±13	0.02 ±0.01	11.9 ±1	31.9 ±2	110 ±5	37.5 ±2	72.5 ±4	900	None	100
B13	Al-Ghadeer	Iraq	20 L	7.4 ±0.06	486 ±10	216 ±5	230 ±8	ND	15 ±4	15.9 ±1	85 ±10	57.5 ±3	27.5 ±1.5	400	None	100
B14	Mona	Iraq	0.5 L	6.4 ± 0.06	59 ±3	18 ±6	21.9 ±2	ND	3.2 ±1	3.5 ±0.5	20 ±3	5 ±1	20 ±2	None	None	None
United States food and drug administration				**6.5-8.5**	**-**	**250**	**250**	**-**	**45**	**250**	**300**	**300**	**75**	**< 2**	**None**	**None**
WHO standard limits				**6.5-8.5**	**-**	**1000**	**500**	**0.4**	**50**		**250-500**	**25-50**	**30-50**	**3**	**None**	**-**
Iraqi Standard Specifications (2001)				**6.5-8.5**	**2000**	**1000**	**250**	**0.4**	**50**	**250**	**500**	**50**	**50**	**None**	**-**	**-**
International bottled water association				**6.5-8.5**	**2000**	**500**	**250**	**-**	**45**	**250**	**300**	**300**	**75**	**None**	**None**	**None**

ND=none detected

The concentrations of nitrate ions (NO_3^-) in all samples varied between 1.1 mg/L in brand 5 to 15 mg/L in brand 13 (Fig.4). These values are within maximum permissible limit prescribed by Iraqi and international recommendations.The maximum permissible concentration of nitrate in drinking water is 50 mg/L. The concentration above permissible values lead to illness in infants below the age of six months with symptoms include shortness of breath and blue baby syndrome [16]. Depending on the results of the statistical analysis nitrate recorded significant positive correlation(r=0.789) with pH.

Highest value of Chloride ion(Cl^-) concentration was recorded in brand 2 (73 mg/L) and the lowest in brand 14 (3.5 mg/L)(Fig.5) . The values recorded in this study were less than the preassemble values for drinking water (250mg/L) in Iraq. Large concentrations of chloride increase the corrosiveness of water and, in combination with sodium, give water a salty taste [16]. Total hardness levels above 500 mg/L are generally considered to be aesthetically unacceptable, although this level is tolerated in some communities [17]. The concentrations of total hardness ranged between 15 to 135 mg/L in all the samples studied for bottled drinking water (Fig.5) and thus be within the allowable values are recommended by the Iraqi and international standard limits.

Also Magnesium (Mg^{+2}) and Calcium(Ca^{+2}) concentrations in the bottled water samples were analyzed as an expression of hardness of water.

Calcium concentration levels in this study varied between 1.5-57.5 mg/L (Fig.5) and this gives us an indication that all samples of the bottled waters within standard limit of 75 mg/L guidelines. Natural water sources typically contained concentrations of up to 10 mg/L for calcium. The taste threshold for the calcium ion is in the range 100 to 300 mg/L, depending on the associated anion, but higher concentrations are acceptable to consumers. Calcium is one of the major elements responsible for water hardness. Water containing less than 60 mg/L of Calcium is considered as soft water.

Magnesium concentrations ranged from13-100 mg/L in all tested samples of studied bottled water(Fig.5). All the bottled water brands had magnesium levels falling within the guideline standards except of the four brands(B1, B2, B6 and B10).

Magnesium, an essential nutrient for plants as well as for animals, is washed from rocks (dolomite, magnesite, etc.) and subsequently ends up in water, being also responsible for water hardness [18]. Important of magnesium intake in drinking water is correlated with multiple health problems. It has long been known that there is relationship between the hardness of drinking water and incidence of cardiovascular diseases. Its concentrations above 500 mg/L give an unpleasant taste and makes it unfit for drinking purposes.

Moreover, only in order to identify the extent of matching the water in bottles with labels on the bottles, which describes the physical and chemical properties of the water, we compared physical and chemical properties of the water with what exists in the labels and the current study showed that the all these brands (except B4 and B14) did not comply with the physical and chemical properties of the water with what exists in the labels and this in turn may lead to adverse health effects for some consumers.

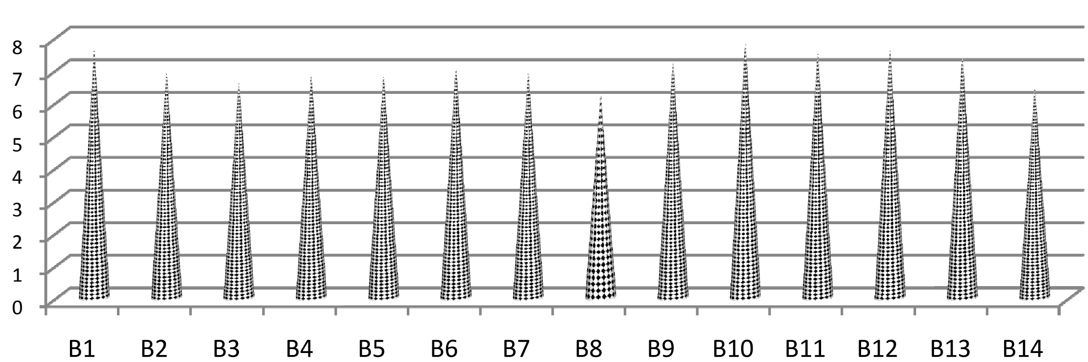

Fig.1: Average pH of analyzed bottled water

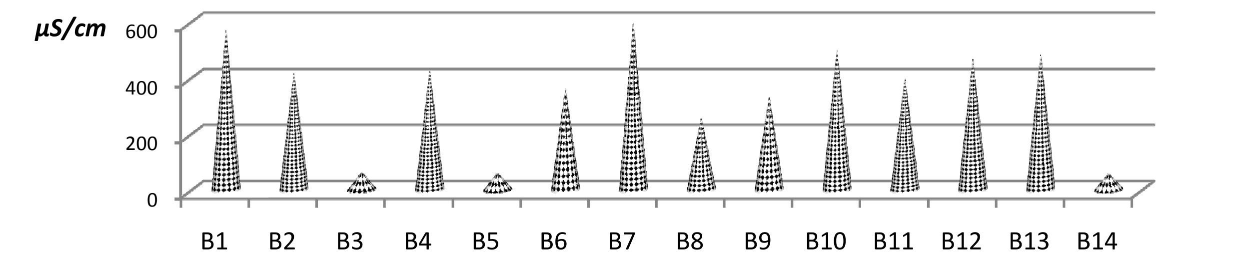

Fig.2: EC valus recorded in all brands of bottled water

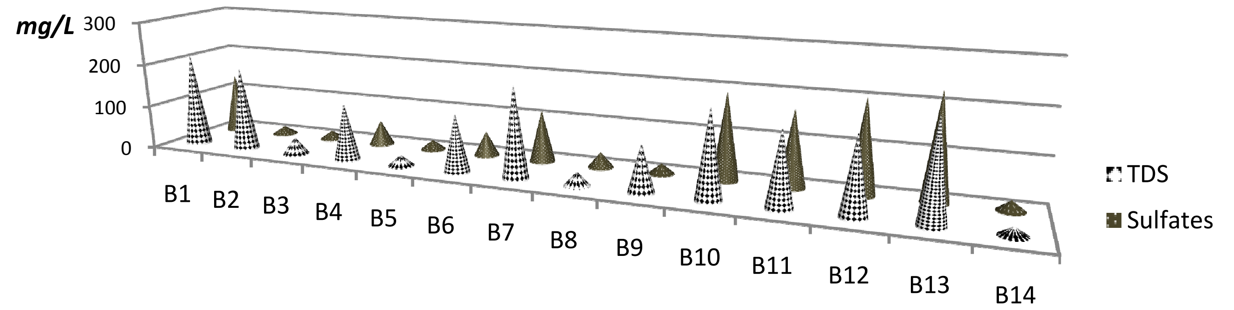

Fig.3: TDS and Sulfates values recorded in all brands of bottled water

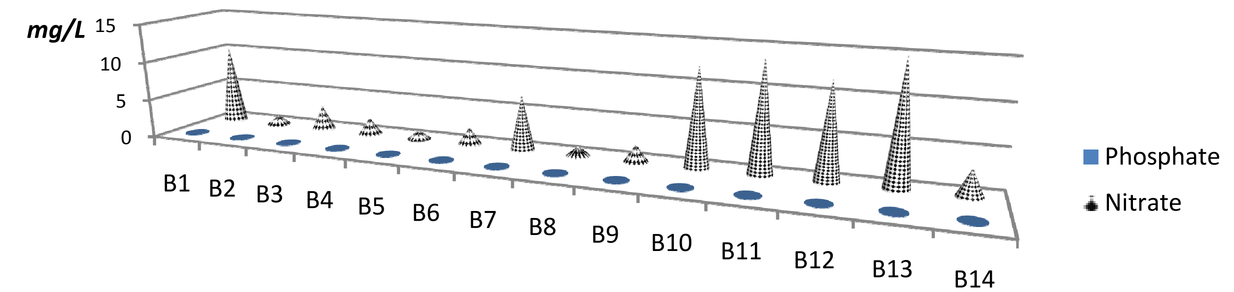

Fig: 4: Phosphate and Nitrate values recorded in all brands of bottled water

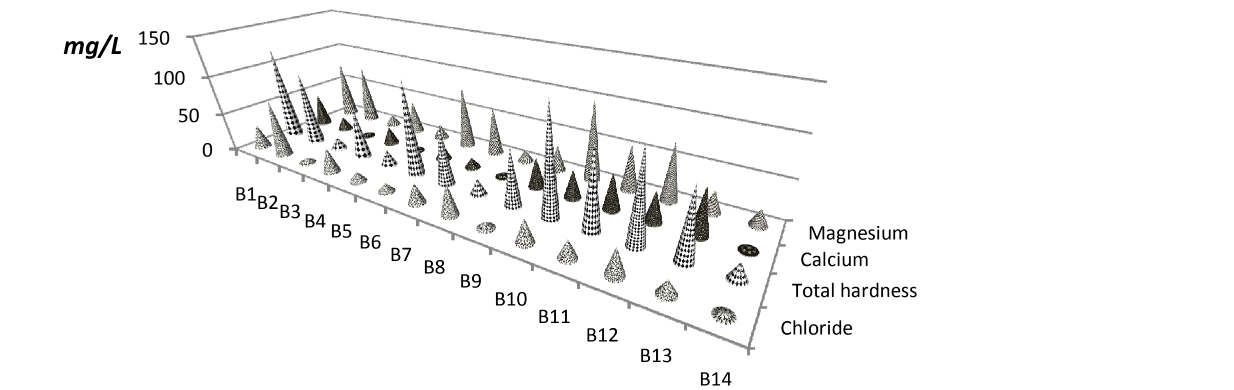

Fig.5: Cl,TH, Ca and Mg values recorded in all brands of bottled water

Microbiological content

The presence of indicator organisms indicates that water is contaminated by potentially dangerous fecal matter and hence their absence denotes in general the water safety. Although coliform organisms may not always be directly related to the presence of fecal contamination or pathogens in drinking water,the coliform test is still useful for monitoring the microbial quality of drinking water[19].The Coliform organisms have long been recognized as a suitable microbial indicator ofdrinking-water quality, largely because they areeasy to detect and enumerate in water [20]. Although coliform organisms may not always be directly associated to the presence of fecal contamination, the presence of coliforms in drinking water suggests the potential presence of pathogenic enteric microorganisms such as *Salmonella spp.,Shigella spp*. and *Vibriocholera*.

In the study of the microbiological properties, the four samples out of 42 samples analyzed were contaminated with total coliform where the number sreached to 400,400,900 and 400CFU/100ml in brands B5,B10,B12 and B13 respectively, moreover compounding the problem is that many of the papers indicated that the viable counts of bacteria increase, notablyin uncarbonated water, to 10400-10500CFU/100ml after 1-2weeks of storage .

However, the finding that 4 brands of the studied bottled water failed to meet the Iraqi and international standard specifications for total coliforms in drinking water should therefore, be of concern. These results suggested the need for an improved surveillance system for the bottled water industry.

The present study revealed that none of examined bottled water samples was contaminated with fecal streptococci (FS) bacteria, suggesting the absence of fecal contamination in these water samples.

The both of brands B10, B12 and B13 contained 100 colony of *Clostridium spp.*/100ml (Table 1). Clostridium spp. are Gram-positive, anaerobic, sulfite-reducing bacilli. They produce spores that are exceptionally resistant to unfavorable conditions in water environments, including UV irradiation, temperature and pH extremes, and disinfection processes, such as chlorination. The characteristic species of the genus,*Clostridiumspp.*is a member of the normal intestinal flora of 13–35% of humans and other warm blooded animals. Like *E. coli* this species are not exclusively of fecal origin and does not multiply in most water environments and is a highly specific indicator of fecal pollution[21].

Nearly, similar results were obtained by Rezouki & Al-Rawy[22]in same area. Prior investigators have postulated bacterial contamination of bottled mineral water. Klont*et al.*[23]reported a contamination rate of 40% among 68bottled mineral water samples collected from 9European and 7 non-European countries. In Iran,of 68 samples, 41 (60%) showed evidences of contamination with common bacterial, including 15 samples(36%) with Gram-positive spore-forming bacilli, 20 samples (49%) with Gram-positive non-spore-forming bacilli and 6 samples (15%) with Gram-positive cocci.[24]. Fajikawa *et al.*[25] found 45 samples of 292 bottled water to be contaminated in Tokyo. In Egypt EL-Batouti [26] noticed that 38.3% of the examined bottled water samples in Alexandria/Egypt were bacteriologically unsatisfactory and failed to meet the Egyptian standards.

CONCLUSIONS

The results presented in this study suggest that the commercially available bottled waters in Baghdad have physical and chemical properties well within the permissible limits sets by Iraqi and international standard specifications for bottled and drinking water except Magnesium ion. While in the study of microbiological properties the results indicated that the four samples returned to four brands contaminated with total coliforms which means probable existence of pathogenic bacteria and 3 samples returned to 3 brands contaminated with very dangerous bacteria(*Clostridiumspp).* The present study indicated clearly to lack of commitment to the health requirements by manufacturers of bottled water, moreover the major parts of the samples studied did not match their specifications with what exists on the labels and this imposes on the both health and the environment ministries as they considered responsible for monitoring manufacturers to follow strictly the work of manufacturers and impose comply to proper health procedures.

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