

## Quality Assessment of Various Local Bottled Waters in Different Iraqi Markets

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### ABSTRACT

Fifteen local bottled waters brands (Best-selling brands) purchased randomly covering nine Iraqi governorates were analyzed for various physico-chemical as well as bacterial water quality parameters. The obtained results were compared to national and international water quality standard for drinking water as well as to the reported label values of the bottled water. Results showed that the majority of bottled water met the different drinking water quality standards for physico-chemical parameters except for calcium (one brand at Baghdad), magnesium (Ten brands at all studied governorates except Basrah) and total alkalinity (Two brands at Baghdad and Duhok). All bottled water brands showed negative growth for fecal coliforms, total coliforms and heterotrophic plate count at 37°C. Generated Piper diagrams revealed that the majority of bottled waters samples are of calcium–magnesium chloride and some sulfate type (Ten brands) and the other water type are of calcium–magnesium bicarbonates (Five brands). Hierarchical cluster analysis was used to classify bottled water brands with similar properties and results distinguished five groups of brands. Comparison of the study results with reported label values indicated considerable variation for pH, Ca, Mg, Na, K, Cl, TH, TA, TDS, EC and SO<sub>4</sub>.

**Keywords:** Bottled Water, Quality Assessment, Iraqi Governorates, Drinking Water Standard, WHO, Cluster Analysis.

## التقييم النوعي لمياه الشرب المعبأة محليا في مختلف الأسواق العراقية

### الخلاصة

تم سحب خمسة عشر عينة عشوائية من المياه المعبأة محليا (الماركات الأكثر مبيعا) من تسع محافظات عراقية وتم تحليلها مختبريا لمختلف المتغيرات الفيزيائية والكيميائية بالإضافة الى البكتريولوجية. وتمت مقارنة نتائج الدراسة مع المعايير المحلية والعالمية لمياه الشرب بالإضافة الى مقارنتها مع القيم الواردة على الملصق لكل زجاجة. وأظهرت النتائج أن غالبية عينات المياه المعبأة محليا كانت ضمن المواصفات المحلية والعالمية لمياه الشرب بالنسبة للمتغيرات الفيزيائية والكيميائية باستثناء الكالسيوم (ماركة واحدة في بغداد) والمغنيسيوم (عشرة ماركات في جميع المحافظات ما عدا محافظة البصرة) والقاعدية الكلية (اثنتين من العلامات التجارية في بغداد ودهوك) فيما أظهرت جميع عينات المياه المعبأة نموا سلبيًا لبكتريا القولون البرازية، العدد الكلي لبكتريا القولون، وأعداد البكتريا المختلفة التغذية عند درجة حرارة 37 مئوية. كما كشف مخطط بايير أن غالبية عينات المياه المعبأة هي من نوع كالسيوم-مغنيسيوم كلوريدات مع بعض الكبريتات (10 ماركات) أما العينات الأخرى فكانت من نوع كالسيوم-مغنيسيوم بيكارونات (5 ماركات). أستخدم التحليل العقودي الهرمي لتصنيف الخمسة عشر عينة مع خصائصها المماثلة وأظهرت النتائج خمسة مجاميع من العلامات التجارية. وأشارت المقارنة بين نتائج الدراسة الحالية مع قيم الملصق لكل زجاجة اختلاف كبير في الأس الهيدروجيني، الكالسيوم، المغنيسيوم، الصوديوم، البوتاسيوم، الكلور، العسرة الكلية، القاعدية، المواد الصلبة الذائبة، التوصيلية الكهربائية والكبريتات.

### INTRODUCTION

Drinking water is considered the most basic needs for ongoing daily consumption to human. (Semerjian, 2011) has defined bottled water as “water that is intended for human consumption and that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents” [1]. The estimated individual needs of drinking water about 2 liters per day for people weighed 60 kg and one liter per day for children weighed 10 kg, depending on the nature of the climate and physical activity and the culture of the community [2]. Bottled water consumption has been growing steadily worldwide during the past three decades [1]. It is considered as one of the fastest growing and most vital of all the food and beverage factories.

Bottled waters should be disinfected and fit for human consumption and compliant to national/international drinking water specifications such as WHO guideline [3] and Iraqi drinking standard [4]. Even though bottled water is disinfected, the microbes and solvents that have been detected throughout groundwater supplies can still be found in bottled water. Campylobacter infection could have wide public health implications and natural mineral water is a risk factor for this [5].

In Iraq, bottled water factories that licensed and approved by General Directorate for Industrial Development estimated as 10 factories with total capacity of 175000 tons/year till the end of 2006 facing 234 factories under-establishing distributed in all Iraqi governorates [6, 7]. The manufacturing bottled water becomes very popular especially after the last war of Iraq in 2003, in which the number of factories represents 54.5% of the overall food and beverage factories that are officially approved by the General Directorate for Industrial Development, according to this, the bottled water industries becomes the widely spreading industry in the country. The growing demand for bottled water in Iraq could be restricted to different reasons such as water scarcity, change in the

characteristics of drinking water quality and foreign communities found after the occupation of Iraq [8]. In addition to weak confidence of consumer in the validity of drinking water supplied from government projects [6], for example, there are seven main stations in Baghdad (capital of Iraq) for drinking water supply, all working with efficiency range between 25% to 63% [9] as shown in Table (1).

(Razuki & Al-Rawi, 2010) have tested 400 bottles of 17 local and imported brands of bottled water in Baghdad (most trading in markets) [7]. They reported that local brands were not within Iraqi standard in case of health requirement. (Almosawi & Alzubaidi, 2010) have microbial assessment of 47 local and imported brands and they concluded that 27 brands were not fit for human consumption [6]. Legally, bottled waters in Iraq should comply with the Iraqi standards to be licensed by General Directorate for Industrial Development. However, to satisfy the local need for bottled water and because of aforementioned reason with economic interests, numerous bottled water suppliers have dumped the Iraqi market, many of which do not have any registration or approved license from General Directorate for Industrial Development. In the absence of official registries, it is difficult to estimate the exact numbers of bottled water brands in Iraq, yet the majority operates without any regulatory authorization. This rapid and untracked increase in the bottled water market prompts concerns about the quality of bottled water marketed in Iraq. This study aimed at evaluating the physico-chemical as well as microbiological quality of selected local bottled waters in different governorates of Iraq. Comparisons of the results to national and international standards as well as to the reported label values are presented. The main objective of this study is to include the Best-selling brands in the Iraqi markets covering nine governorates.

**Table (1) Efficiencies of water treatment plants in Baghdad during seven consecutive years.**

WTPs	Efficiency %						
	2002	2003	2004	2005	2006	2007	2008
ALKARKH	60.97	60.86	60.57	54.93	63.2	57.07	60.06
EAST TIGRIS	60.62	61.45	61.19	57.86	63.3	57.43	49.08
AL KARAMAH	39.47	44.52	38.79	39.3	34.5	35.87	30.14
AL WATHBAH	42.85	46.56	40.69	39.67	33.87	34.07	30.17
AL QADISIYH	29.03	34.96	33.99	31.45	31.86	29.36	29.69
AL DAWRAH	25.07	35.22	33.49	32.47	30.1	29.52	30.07
AL RASHID	31.26	36.22	30.66	33.18	34.16	31.26	28.84

Source: (Alobaidy et al. 2010) [9]

**MATERIALS AND METHODS**

In this study, 15 local brands of bottled waters were bought in duplicate containers during fall (2011) from randomly selected shops and super-markets located in different parts of Iraqi governorates. Container sizes of the selected samples ranged between 0.5 and 0.6 L in volume except one sample (1.5 L). Table (2) shows the brand name of the selected samples, size, manufactured company and place of manufacture. The conducted analyses included physical parameters which are turbidity, electrical conductivity (EC) and total dissolved solids (TDS); chemical constituents such as pH, total alkalinity, total hardness, chloride (Cl<sup>-</sup>), nitrate (NO<sup>-3</sup>), sodium (Na<sup>+</sup>), potassium (K<sup>+</sup>), calcium (Ca<sup>++</sup>), magnesium (Mg<sup>++</sup>), and sulfate (SO<sub>2</sub><sup>-4</sup>); as well as microbiological parameters such as fecal coliforms (FC), total coliforms (TC), and heterotrophic plate count (HPC) at 37°C. Table (3) shows the technical/method used for the analysis of different parameters, alongside some of the abbreviations and units used in this study.

All samples were stored in their original sealed containers in refrigerated conditions prior to completing related analyses at chemical laboratory of water resource techniques department, institute of technology. Certain analyses were carried out in the Environment Directorate of Baghdad, Ministry of Environment. Analysis given by [10] was followed to obtain the specification of the water samples.

In order to reveal the water type of investigated bottled waters Piper diagrams has been generated in this study with the help of GW\_Chart software v. 1.19.0.0 [11].

**Table (2) Brand name, size, manufactured company and place of manufacture of the selected samples.**

<b>Brand Name</b>	<b>Brand Code</b>	<b>Size of Brand</b>	<b>Manufactured company</b>	<b>Disinfection</b>	<b>Governorate</b>
Hadeer	1	0.5 L	Al-Noaman company for healthy water	Ozone	Baghdad
FURAT	2	0.6 L	Al-Furat company for healthy water	Ozone	Baghdad
AlAIN	3	0.6 L	Albarakah factory for healthy water and beverage	-	Baghdad
Al-Muttahida	4	0.5 L	Al-Hny factory for mineral water	U.V & Ozone	Baghdad
Mina	5	0.5 L	Mina company for healthy water	U.V & Ozone	Kirkuk
Altoon HAYAT	6	0.5 L	Altoon Hayat factory for healthy water	-	Kirkuk

Al-Khaleej	7	0.6 L	Al-Khaleej company for healthy water	Ozone	Basrah
Salsal	8	0.5 L	Salsal company LTD	Ozone	Basrah
ALA	9	0.5 L	ALA company	Ozone	Sulaymaniyah
Saqi Alkawthar	10	0.5 L	-	Natural Aquifer Water	Wasit
Crystal	11	1.5 L	Karbala company for soft drink & mineral water	Ozone	Karbala
Rovian	12	0.5 L	Rovian mineral water bottling plant	Spring Water	Duhok
Jin	13	0.5 L	Rawita Group Company	Spring Water	Duhok
Source of OASIS	14	0.5 L	Alwaha company for beverage water, soft drink and juices	Ozone	Babylon
Raheeq	15	0.5 L	Alnawaras company for drink & healthy water	U.V & Ozone	Diyala

**Table (3) Analytical method, Abbreviation, units for water quality variables.**

Parameter	Abbreviation	Units	Instruments / technique used
pH	pH	-	Digital pH meter
nitrate nitrogen NO <sub>3</sub> -N,	NO <sub>3</sub> <sup>-</sup>	mg/L	Colourimetric
Total Hardness	TH	mg/L	EDTA Titrimetric method
Turbidity	TBR	NTU	Digital Turbidity Meter
Fecal coliform	FC	CFU/100 ml	Membrane filtration technique
Total coliform	TC	CFU/100 ml	Membrane filtration technique
Heterotrophic plate count	HPC	CFU/mL	HPC spread plate method
Sodium	Na	mg/L	Flame-photometric
Calcium	Ca	mg/L	Titrimetric method
Magnesium	Mg	mg/L	Titrimetric method
Total dissolved solids	TDS	mg/L	Temperature controlled oven
Total Alkalinity	TA	mg/L	Titration method

Electrical conductivity	EC	µs/cm	Measured by conductivity meter
Chloride	Cl <sup>-</sup>	mg/L	Silver nitrate method
Sulphate	SO <sub>4</sub> <sup>2-</sup>	mg/L	Turbiditymetric
Potassium	K	mg/L	Flame-photometric

### CLUSTER ANALYSIS

The term cluster analysis encompasses a number of different algorithms and methods for grouping objects of similar kind into respective categories. In other words cluster analysis is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess. Cluster analysis classifies objects so that each object can be similar to the others in the cluster with respect to a predetermined selection criterion. Hierarchical agglomerative clustering is the most common approach, which provides intuitive similarity relationships between any one sample and the entire data set, and is typically illustrated by a dendrogram (tree diagram) [12, 13]. Euclidean distance method was used for determining distance. This is probably the most commonly chosen type of distance. It simply is the geometric distance in the multidimensional space and is computed as:

$$\text{Distance}(X, Y) = \left\{ \sum i(X_i - Y_i)^2 \right\}^{1/2} \quad \dots (1)$$

In this study, the data sets observed of the bottled water during 2011, are also analyzed with CA analysis to show the similarity and dissimilarity between bottled water using Statistical Package for the Social Sciences Software - SPSS 17 for Windows.

### RESULTS AND DISCUSSION

#### Physico-chemical quality

The physico-chemical composition of analyzed Iraqi bottled waters is summarized in Tables 4. Physico-chemical properties range between 7.2 and 9.4 (mean = 8.5) for pH, 24 and 440 µS/cm at 25°C (mean = 214.6 µS/cm at 25°C) for EC, 55 and 254 mg/L (mean = 133.06 mg/L) for TDS, 0.2 and 2.5 NTU (mean = 1.53 NTU) for turbidity, 50 and 250 mg/L as CaCO<sub>3</sub> (mean = 123.3 mg/L as CaCO<sub>3</sub>) for total hardness, 9 and 150 mg/L as CaCO<sub>3</sub> (mean = 57.9 mg/L as CaCO<sub>3</sub>) for total alkalinity. The major ionic composition of bottled waters varies between 5 and 40 mg/L (mean = 18.6 mg/L) for Cl<sup>-</sup>, 4 and 90 mg/L (mean = 28.1 mg/L) for SO<sub>4</sub><sup>2-</sup>, 0 and 24 mg/L (mean = 4.28 mg/L) for NO<sup>-3</sup>, 20 and 76 mg/L (mean = 45.3 mg/L) for Ca<sup>+2</sup>, 26 and 144 mg/L (mean = 70.4 mg/L) for Mg<sup>+2</sup>, 2 and 28 mg/L (mean = 10.04 mg/L) for Na<sup>+</sup>, 0.1 and 1.3 mg/L (mean = 0.63 mg/L) for K<sup>+</sup>.

**Table (4) Physico-chemical properties of investigated bottled water brands.**

Brand Code	pH	TD S	TBR	TH	EC	Ca	Mg	Cl	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	NO <sub>3</sub>	Na	K
1	7.8	216	2.5	250	221	76	144	40	0	132	90	1.8	19	1.3
2	8.3	116	2	90	209	48	42	20	0	44	26	1.3	15	1.1
3	8.5	166	1	210	306	52	118	30	0	64	51	0.4	6	0.6
4	8.4	101	1.5	190	188	56	90	10	0	66	22	0.2	2.6	0.3
5	8.2	75	2	90	141	64	26	10	0	62	5	0.9	5	0.8
6	7.9	100	2	90	187	28	62	15	0	55	8	18	9	0.6
7	8.7	55	2	50	24	20	30	5	0	9	4.5	0	2.7	0.1
8	7.8	83	2	100	49	56	44	5	0	15	8	0	7	0.4
9	9.3	86	1.3	80	152	20	60	5	0	117	5	13	2.1	0.1
10	8.9	138	1.5	130	241	44	86	10	0	31	79	3	28	1.2
11	8.9	164	2	120	283	56	64	5	0	24	32	0.3	22	1
12	8.9	173	2	70	304	36	34	40	0	150	4	24	2.3	0.3
13	9.4	105	0.5	100	189	28	72	20	0	56	22	0.4	2	0.2
14	9.4	164	0.5	110	285	40	70	25	0	11	40	0	19	0.9
15	7.2	254	0.2	170	440	56	114	40	0	33	25	0.9	9	0.6

\* All values in mg/L except pH, EC ( $\mu\text{s}/\text{cm}$ ) and TBR (NTU)

Comparing with various national and international standards of quality for bottled waters Table (5), recorded concentrations are within acceptable ranges except for calcium (1 brand at Baghdad governorate, 6.67% of samples), magnesium (10 brands at all studied governorates except Basrah, 66.6% of samples), and total alkalinity (2 brands at Baghdad and Duhok, 13.3% of samples). However, such violations do not pose major health concerns such as pH which categorized as a secondary water standard by the USEPA [1], whereas calcium and magnesium in drinking waters does not regulated except by Iraqi Drinking Standard. Furthermore, only two brands name at Kirkuk and Duhok governorates showed nitrate levels exceeding 15 mg/L, the level specified by [14] to classify water as suitable for baby food and formula preparations.

The chemical characteristics of the bottled water composition, on the basis of major ion concentrations, were evaluated on a Piper diagram Figure (1). When the concentrations of the elements are evaluated, it can readily be seen that there are two types of the investigated bottled water in Iraq. First, water (10 brands) that is relatively rich in calcium–magnesium chloride and some sulfate, which can be seen in Baghdad, Basrah, Wasit, Karbala, Babylon, Diyala and Duhok. The second type of water (5 brands) is relatively rich in calcium–magnesium bicarbonates probably originating from limestone aquifers, which can be seen in Baghdad, Duhok, Sulaymaniyah and Kirkuk.

**Table (5) National and international standards related to bottled water quality.**

Parameter	Unit	Iraqi Drinking Standard (2001) Maximum permissible limits	WHO (2006) Guide line for drinking water	FDA (2008) Bottled water(Maximum admissible concentration) [15]
pH	-	6.5-9.2	6.5-9.5 <sup>b</sup>	-
TDS	mg/L	500	1000 <sup>b</sup>	500 <sup>e</sup>
Turbidity	NTU	5	5 <sup>c</sup>	5
Total Hardness	mg/L	100	500 <sup>b</sup>	-
Total Alkalinity	mg/L	125	-	-
Chloride	mg/L	200	250	250 <sup>e</sup>
Sulfate	mg/L	200	250 <sup>d</sup>	250 <sup>e</sup>
Nitrate	mg/L	40 <sup>a</sup>	50	44
Calcium	mg/L	75	-	-
Magnesium	mg/L	50	-	-
Sodium	mg/L	200 <sup>a</sup>	-	-
potassium	mg/L	-	-	-
Conductivity	µs/cm	2000 <sup>a</sup>	-	-
Fecal coliforms	CFU/100 mL	0	0	-
Total coliforms	CFU/100 mL	0	0	<4
Heterotrophic bacteria	CFU/100 mL at 37°C	-	-	-

a) Values considered as maximum allowable limits

b) Non-enforceable limits by WHO above which consumer complaint may arise

c) Guidelines for Drinking Water Quality, 3rd Edition, Geneva, 1984.

d) Guidelines for Drinking Water Quality, 1993.

e) Mineral water is exempt from allowable level. The exemptions are aesthetically based on the allowable levels and do not relate to a health concern.



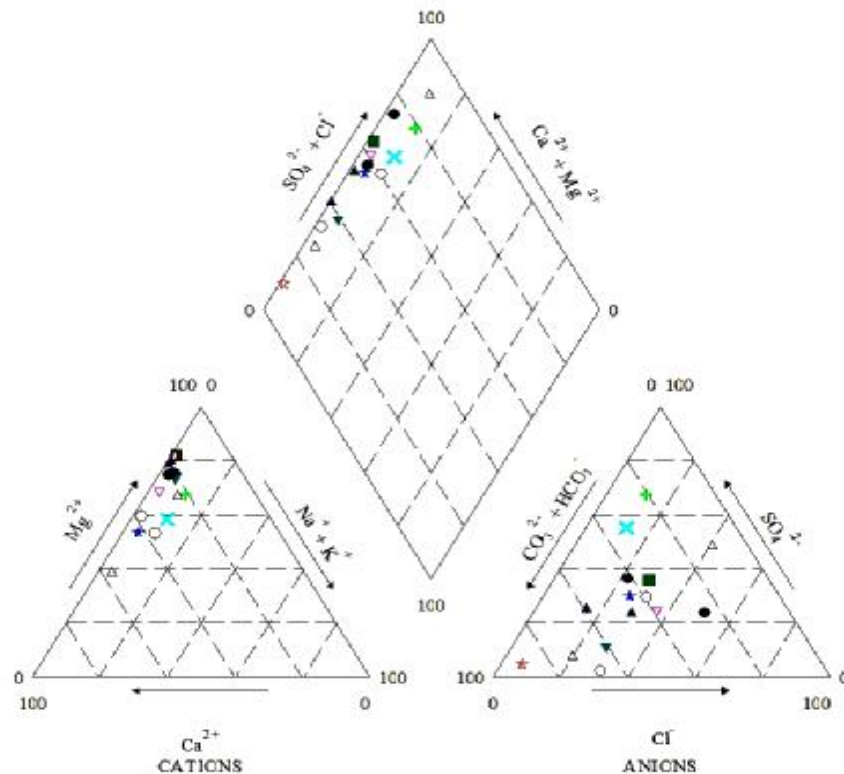


Figure (1) Piper Diagram showing the major ionic composition of the sampled bottled water at different Iraqi governorates.

#### MICROBIOLOGICAL QUALITY

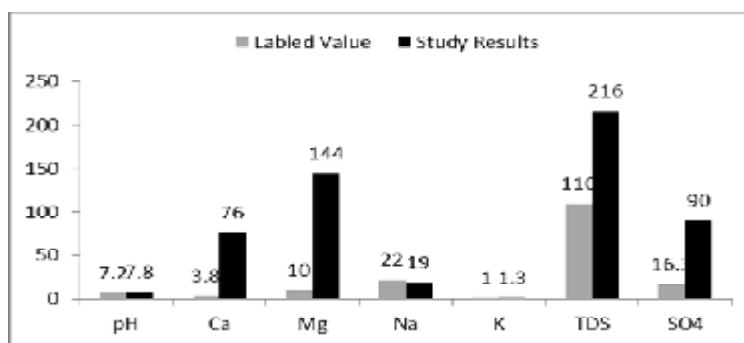
The microbiological quality of investigated bottled waters was assessed in terms of indicator microorganisms (FC and TC) as well as heterotrophic plate count at 37°C. These indicator microorganisms are indicative of the presence of pathogens that may cause numerous water-borne diseases. Moreover, the presence of fecal coliforms indicates contamination with wastewater, which further aggravates health conditions. The 37°C HPC can provide an indication of fast-growing saprophytic bacteria that grow on biodegradable organic matter and possibly relate to pathogenic types [1]. The presence of pathogens that may cause water-borne diseases does not always arising from wastewater contamination. In bottled water, such bacteria may be indigenous from the natural source of the water or may be introduced during processing. It has also been established that a number of these bacteria could multiply during storage to reach infective doses for consumers [16]. The rapid growth of bacteria after the water is bottled may be due to the increased surface area from the bottle, the increase in temperature during storage, and the trace amounts of nutrients arising from the bottle [17].

Analyzed bottled waters revealed that all the samples showed negative growth for fecal coliforms, total coliforms and HPC at 37.C.

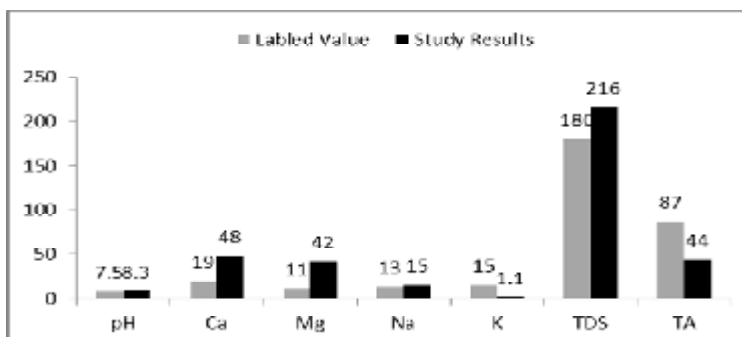
**COMPARISON OF THE STUDY RESULTS WITH THE REPORTED LABEL VALUES**

The variation of recorded results from the reported label values for pH, Ca<sup>++</sup>, Mg<sup>++</sup>, Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, TH, TA, TDS, EC and SO<sub>4</sub><sup>-2</sup> were assessed and presented in Figures 2a to 2n. The label values of the brand coded 5 is missing due to unclear values reported on the label. The Figures 2a - 2n were made based on the availability of the reported values in each of bottled water label. From the Figures 2a – 2n, it can be seen that there is a large variation between the obtained results and the reported values in most parameters. In some cases, the label values were higher than the recorded values and vice versa, the label values were lower than the recorded values. Among the observed variation for the assessed parameters, pH levels showed the lowest variation. The observed pH values of all bottled water brands were alkaline, and highest values recorded in the brands 7, 9, 10, 11, 12, 13, 14, which can be seen in Basrah, Sulaymaniyah, Wasit, Karbala, Duhok and Babylon.

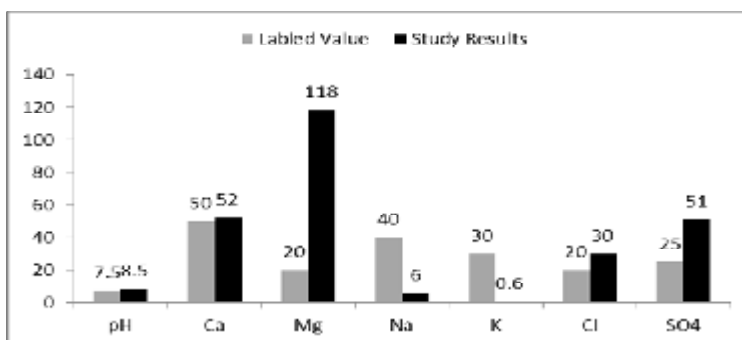
For all the other parameters, the variation between the analyzed and reported values was very high. The water quality parameters that showing high variations in brand 1 are Ca, Mg, TDS and SO<sub>4</sub> as shown in Figure (2a); brand 2 (TA, K, TDS, Mg and Ca) Figure (2b); brand 3 (Mg, K, SO<sub>4</sub>, Cl and Na) Figure (2c); brand 4 (Mg, Ca and SO<sub>4</sub>) Figure (2d); brand 6 (Mg, Cl and SO<sub>4</sub>) Figure (2e); brand 7 (Mg, Ca, Na, TDS and TH) Figure (2f); brand 8 (Mg, Ca, SO<sub>4</sub> and Cl) Figure (2g); brand 9 (Mg, Ca, Na, SO<sub>4</sub> and K) Figure (2h); brand 10 (Mg, Cl, TA and SO<sub>4</sub>) Figure (2i); brand 11 (Ca, Mg, TDS, TH and SO<sub>4</sub>) Figure (2j); brand 12 (Ca, Mg, TDS, and EC) Figure (2k); brand 13 (Ca, Mg, and TH) Figure (2l); brand 14 (Ca, Mg, TDS and TH) Figure (2m); brand 15 (Mg, Ca, Na, SO<sub>4</sub> and K) Figure (2n). It could be concluded that the majority of marketed bottled waters at different governorates, especially the brands without any registration or approved license from General Directorate for Industrial Development, may not always have uniform composition and may not always adhere to reported label values, which increases health risks associated with drinking water.



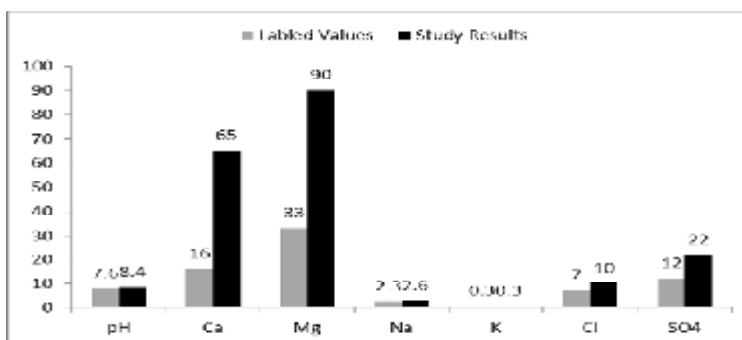
**Figure (2a) Comparison of study results with the reported Label Values of the brand coded 1.**



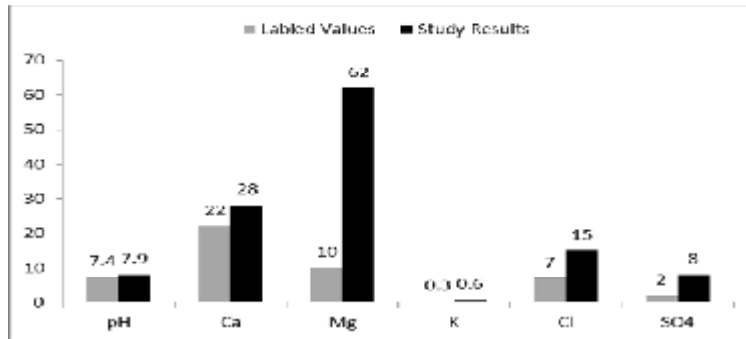
**Figure (2b) Comparison of study results with the reported label Values of the brand coded 2.**



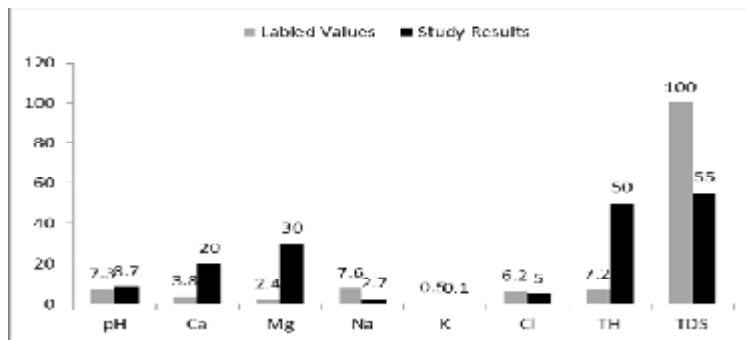
**Figure (2c) Comparison of study results with the reported label values of the brand code 3.**



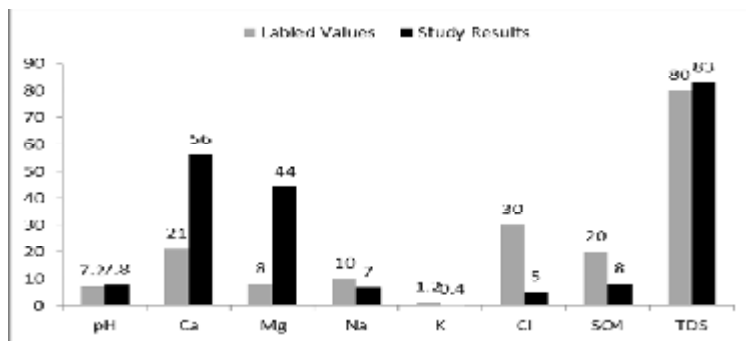
**Figure (2d) Comparison of study results with the reported label values of the brand code 4.**



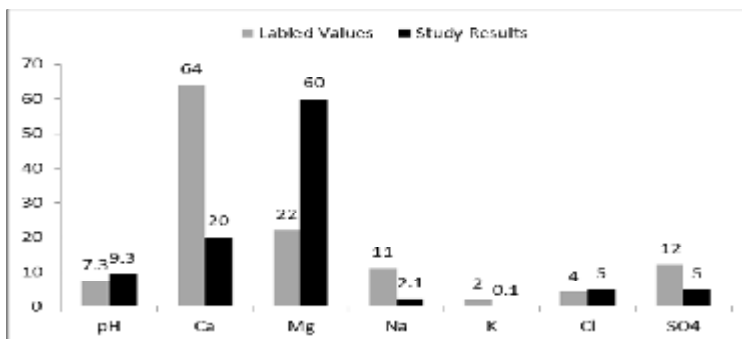
**Figure (2e) Comparison of study results with the reported label Values of the brand code 6.**



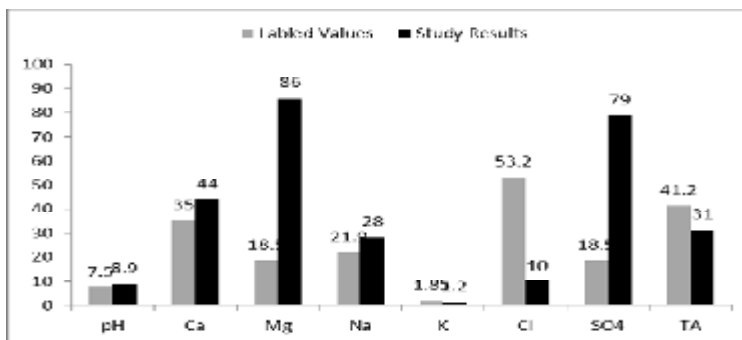
**Figure (2f) Variation of study results with the reported label Values of the brand code 7.**



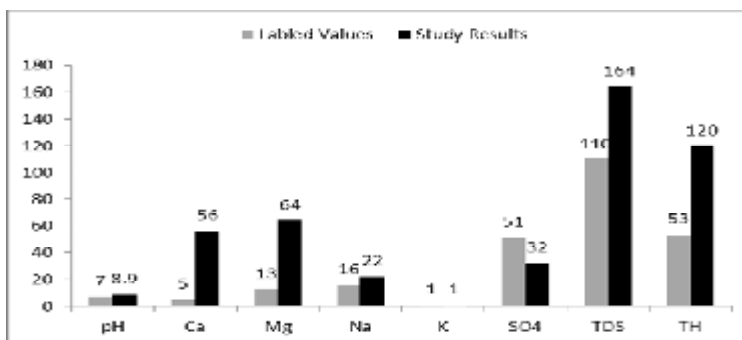
**Figure (2g) Variation of study results with the reported label Values of the brand code 8.**



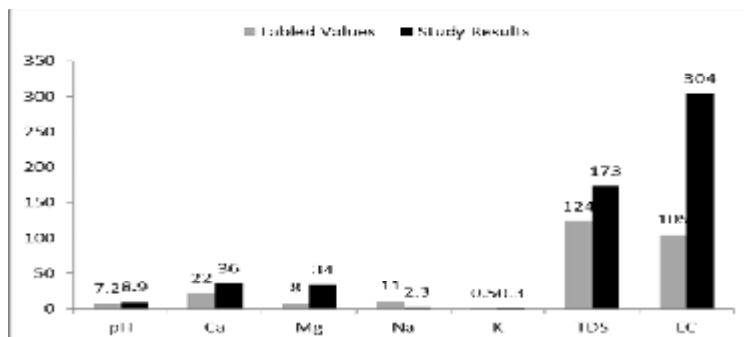
**Figure (2h) Variation of study results with the reported label Values of the brand code 9.**



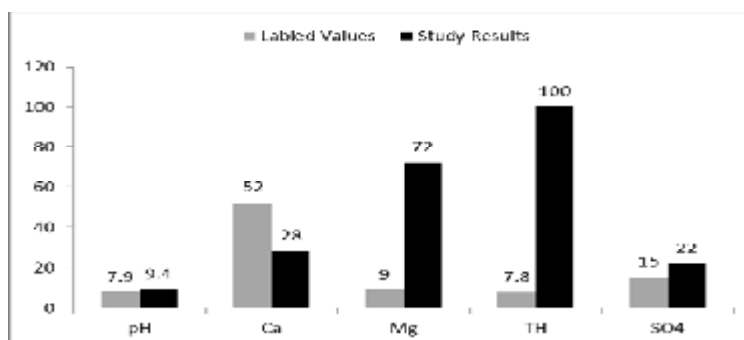
**Figure( 2i) Variation of study results with the reported label Values of the brand code 10.**



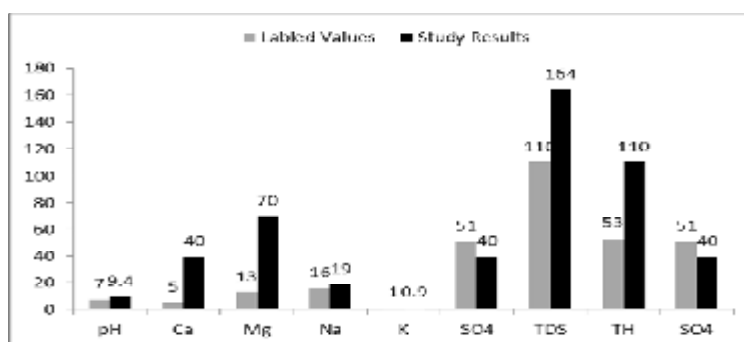
**Figure ( 2j) Variation of study results with the reported label Values of the brand code 11.**



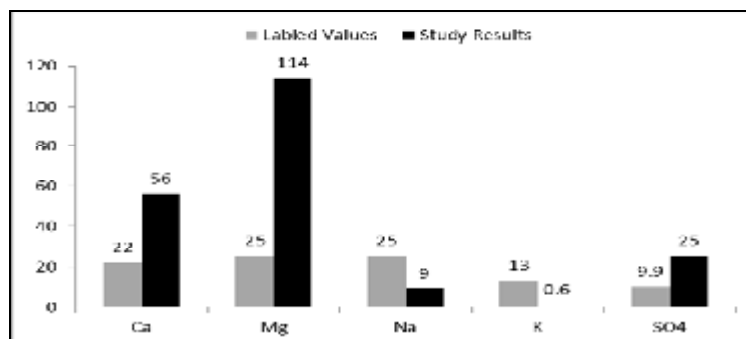
**Figure (2k)** Variation of study results with the reported label values of the brand code 12.



**Figure (2l)** Variation of study results with the reported label Values of the brand code 13.



**Figure (2m)** Variation of study results with the reported label Values of the brand code 14.



**Figure (2n) Variation of study results with the reported label Values of the brand code 15.**

### CLUSTER ANALYSIS

In this study bottled water classification was performed by the use of cluster analysis. The results of cluster analysis CA are presented in a dendrogram. Dendograms in cluster analysis provides a useful graphical tool determining the number of clusters which describe underlying process that lead to spatial variation [18]. A total of five groups were identified based on cluster analysis Figure (3) as follows:

Cluster I (Brands 2, 4, 5, 6, 9, and 13):

These brands were determined to have close specifications based on all variables examined. These brands are belonging to Baghdad, Duhok, Kirkuk and Sulaymaniyah.

Cluster II (Brands 3, 10, 11 and 14):

These brands were determined to show similar characteristics. They are belonging to Baghdad, Wassit, Karabala and Babylon.

Cluster III (Brand 12):

This cluster consist one brand belonging to Duhok governorates. This brand has the highest  $\text{HCO}_3$  concentrations with high value of TDS and EC compared to the other analyzed brands. Furthermore, the highest common concentration of Cl was found in this brand.

Cluster IV (Brands 1, 7, 8):

These brands are belonging to Baghdad and Basrah.

Cluster V (Brands 15):

This cluster consist one brand belonging to Diyala governorates. The brand has the highest TDS concentrations with high values of EC and Mg compared to the other analyzed brands. Furthermore, the highest common concentration of Cl was found in this brand.

Bottled water samples, even if collected from the same governorates, showed various specifications based on examined variables. Hence, a governorate -wide generalization about water quality cannot be made in Iraq. Site-specific features should be always kept in mind [19].

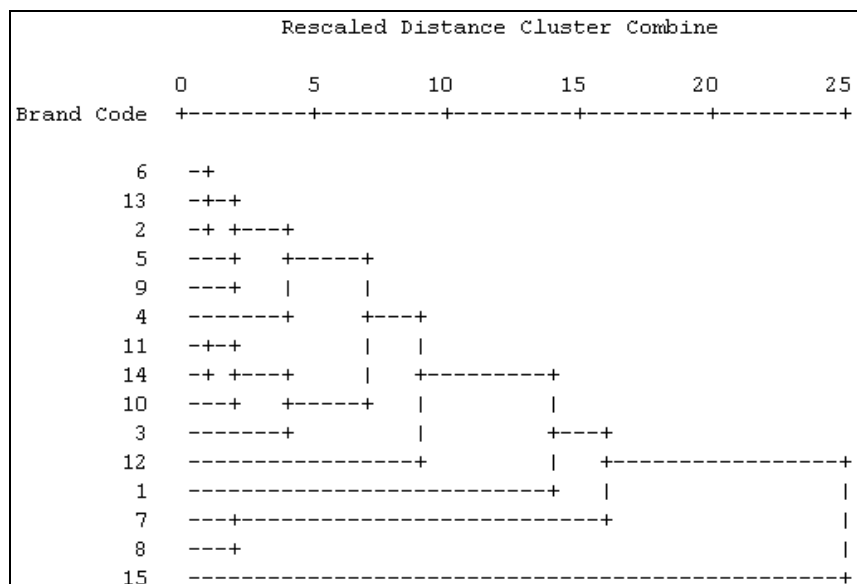


Figure (3) Hierarchical cluster analysis based on average linkage between bottled water brands (The axis shown at the top indicates the relative Similarity of different cluster groups. Lesser distance corresponds to greater similarity between brands).

### CONCLUSIONS

In Iraq, people prefer using bottled water than tap water for a number of reasons such as water scarcity, change in the characteristics of drinking water quality and foreign communities found after the occupation of Iraq, in addition to weak confidence of the consumer in the validity of drinking water supplied from government projects. Analysis of 15 bottled waters in Iraq shows a wide spread in the composition for most of the selected parameters. The majority of bottled water met the different drinking water quality standards for physico-chemical parameters except for calcium, magnesium and total alkalinity. No bacteriological contaminations were observed in the bottled water brands. From piper diagram, two types of bottled water in the Iraqi governorate. First type is relatively rich in calcium–magnesium chloride with sulfate and the other type is rich in calcium–magnesium bicarbonates. Hierarchical cluster analysis grouped 15 bottled water brands into five clusters of similar water quality characteristics.

This study covers a limited number of bottled waters available in Iraqi local market; it is recommended that all bottled waters should be monitored for quality and be licensed by General Directorate for Industrial Development to safeguard consumers' health. Extensive studies are required to evaluate the quality of recyclable bottled water of 20 L in size and quality comparison of tap water versus bottled water in Iraqi governorates.



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