زانکۆی سەلاحەددین-هەولێر

Salahaddin University-Erbil

Assessing the quality of bottled water brands in Erbil, Kurdistan Region of Iraq

Research project

Submitted to the department of biology in partial fulfillment of the requirements for the degree of B.Sc. in Biology.

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April-2024

SUPERVISOR CERTIFICATE

This research project has been written under my supervision and has been submitted to the department of biology for the award of the degree of B.A. in biology with my approval as supervisor.

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Date: **April 1, 2024**

I confirm that all requirements have been fulfilled.

Signature:

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Head of the Department of biology

Date: **April 1, 2024**

Dedication

I dedicate this work to

My parents …

Helin

Acknowledgements

To begin with, I thank (**Allah**) for his blessing who made me able to complete and perform this study with success.

My gratitude and appreciation are dedicated to the presidency of Salahaddin University-Erbil, the deanery of College of Education and to the head of Biology Department for their necessary facilities during the work.

My family deserves a particular thank you for supporting me throughout my whole academic career and enabling me to pursue a university education.

My sincere appreciation to my supervisor, Dr. Abdulla Hamad Aziz for his unfailing support and direction throughout this project.

The rest of my family members for their encouragements, love, care and support. Finally, I thank all those who assisted me in doing my work.

Summary

In the present study a total of fifteen brands of drinking bottled water brands available commercially were selected in Erbil city during January 2024. The samples were analyzed for pH, EC, TDS, Cl^-, Total Alkalinity, Total Acidity, Total Hardness, Nitrite-NO_2, Nitrate-NO_3 and PO_4^3. The results showed that pH value ranges (6.7 – 7.6), accordingly, all studied bottled water brands in Erbil city do not exceed the allowable limits of 6.5-8.5.

Electrical conductivity EC results showed that Mira, Ballak and Tiyan brands characterized by high levels of EC and it was 246, 239 and 223 µS cm^{-1} respectively. While Aljoud water has the lowest EC value of 38 µS cm^{-1} among the studied samples. The rest of the brands were with EC values between 100 and 200 µS cm^{-1}. Total dissolved solids TDS Mira, Ballak and Tiyan brands characterized by high levels of TDS and it was 123, 119 and 111 mg/l respectively. Whereas, Aljoud water was with the lowest TDS value of 19 mg/l.

Chloride ion concentration ranged between 1.99 and 39.70 mg/l in Aquafina and Massafi bottled water brands respectively. Bottled water brands Aquafina, Aljoud, Alwaha and Ballak characterized by low levels of chloride while Crystal, Kani and Massafi contain high levels of chloride. revealed that the value ranged from 8 to 60 mg/l in Alwaha and Kani respectively. Alwaha, Aquafina, Ballak and Mira characterized by low levels of Alkalinity while Hawler, Kani, Rovian and Sulav contain high levels of Alkalinity. Total hardness ranged from 5 mg/l in Mira to 35 mg/l in Tiyan brand. All studied bottled water brands remained in safe levels of 250 mg/l during the studied period.

Nitrite concentration ranged from 0.34 to 0.91 mg/l in Rovian and Mira brands respectively. Nitrate concentration ranged from 0.1 to 1.59 mg/l in Sulav and Life brands respectively. Generally, Life, Alwaha and Lava characterized by low levels of nitrate while Sulav, Crystal, Hawler, Massafi and Rovian contain high concentration of nitrate. All studied bottled water brands were below the maximum permission level of 10 mg/l. The phosphate concentration ranged between 0.24 to 0.82 mg/l in Crystal and Massafi brands respectively. Crystal, Hawler, Kani, Life and Mira characterized by low levels of phosphate, whereas, Massafi, Aquafina, Slemani and Tiyan were contain high levels of phosphate.

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Chapter One

1. Introduction

Water is an essential natural resource for sustainability of life on earth, only 1 % is accessible for human consumption (Chinedu, *et al*. 2011). The main source of bottled water sold in Kurdistan region is from springs, wells and surface water. The quality of water may vary from one source to another based on several parameters such as water sources, type of water purification, and storage tanks. There has been a considerable increase in the consumption of bottled water in Kurdistan region, especially in the summer (Muhamad**,** *et al*. 2011). The quality of bottled water can also substantially vary among brands as well as with time and with different production runs depending on its source, treatment technology, manufacturing operation, packaging material, and shelf-life before use (Abd El-Salam, *et al.* 2008*).*

In general, the quality of water is equally important as its quantity, therefore; water quality is considered as the factor to judge environment changes which are strongly associated with social and economic development. The most important characteristic of bottled water over tap water is the quality, especially in terms of taste and regularity (Kassir, *et al.* 2015). Pure water is probably the most important resource on earth (Baba, *et al*. 2008). Generally, bottled water should not contain any substances that affect color, odor and taste. The bottled water could contain chemical pollutants or bacteria or natural toxic substances (Al-Zahrani, *et al*. 2017).

Water was not that popular as a packed food item even a decade ago (Rahman, *et al*. 2017). Only 1% of the existing water resources on the entire planet can be used for human consumption. The remaining 99% of the existing water resources consist of 97% saltwater and 2% ice caps (Almnehlawi, 2013). On the other hand, one of the main causes of the increasing bottled water consumption is the belief that is healthier than tap water (Font-Ribera, *et al*. 2017). Bottled water is defined 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 (Semejian, 2011).The human dietary requirement for water is estimated to be approximately two liters per day for a mean adult (Kadhim, *et al*. 2017).

Drinking water with different qualities is now bottled and sold for public consumption throughout the world (Al-Omran, *et al*. 2012). Consumption of bottled water around the world is rapidly increasing by an average of 7% each year, in spite of its excessively high price compared

to tap water and although industrialized countries consumers have access to cheap good quality tap water (Alfadul and Khan, 2011).The water sources for bottled drinking water are usually bore-holes and they differ in content due to the composition of the bedrock of the well (Rosborg, *et al.* 2005). Even the accessible drinking water would require series of treatments before it could be safe or fit for drinking (Toma.2013).

Water quality indices are useful tools for assessing the overall quality of waters (Tsakiris, 2016). It is well- known that water contains chemical elements which play an important role in daily human nutrition, but is also true that major and trace elements, essential and non-essential elements, may be unhealthy or even toxic when concentration exceeds certain levels (Varrica, *et al*. 2013). The aim of the present study is to evaluate water quality of different bottled waters available commercially in Erbil city, Kurdistan Region of Iraq.

Chapter Two

2. Literature Review

During the last two decades several studies conducted worldwide. Among them, Smedly, 2010 studied the inorganic chemistry of bottled mineral waters from the British Isles. All samples analyzed in the study had concentrations of inorganic constituents well within the limits for compliance with European and national standards for bottled waters. Muhamad**,** *et al*. 2011 studied effect of storage temperature and sunlight exposure on the physicochemical properties of bottled water in Kurdistan region-Iraq. Results indicated that the quality of bottled water samples was within the permissible limit, while it is changed with the time of sunlight exposed or temperature changes.

Kassir, *et al.* 2015 quality assurance for Iraqi bottled water specifications. The results also highlighted the weakness of quality assurance activities since only 33 % of the investigated companies registered the whole water quality specifications.

Abd El-Salam, *et al.*2008 studied quality of bottled water brands in Egypt in the biological water examination. More than half (54.8%) of biological parameters were violated the Egyptian standards. Baba, *et al*. 2008 they studied fifteen bottled mineral waters purchased at random all over Turkey were analyzed for their chemical composition. Such a comparison shows that, except for Ba and Mn, the concentrations of the other heavy metals are lower than the limit of the US.EPA in Turkey. Al-Zahrani, *et al* 2017 they reviewed the quality of bottled water furnishing a baseline survey for its production and management in the Eastern Region of KSA. Carried out research showed that most bottled waters from KSA factories are safe and proved to be of high quality and relatively free of contaminants.

Rahman, *et al*. 2017 they studied quality of the non- carbonated bottled drinking water marketed in Bangladesh and comparison with tap water. The characteristics are matched with the very low or low mineral content category with a hint of saline character and very soft-hardness in most, followed by a suitability for low sodium diets.

Almnehlawi. 2013 his study aimed to evaluation quality of ten brands bottled drinking water that sold in local markets of Samawa city.Statistical analysis results showed significant differences between brands for most tests. Font-Ribera, *et al*. 2017 the aim of their study to describe personal and tap water quality determinations of bottled water use in the city of Barcelona. More than half

of Barcelona residents regularly drank bottled water and the main determinant was the chemical composition of tab water.

Kadhim, *et al*. 2017seventeen bottled samples were collected from local markets which were different bottles size and trade markets. shows all samples were within the permissible limits for Iraqi criteria and standards for bottled water. Semejian.2011 studied thirty-two domestic bottled water brands were analyzed for various physico-chemical as well as bacterial water quality parameters Comparison of the study results with reported label values indicated good agreement with stated pH values but considerable variation for dry residue, Mg, Na, K, Ca, Mg, HCO_3, Cl, and SO_4.

Al-Omran, *et al*. 2012 their study focuses on the chemical analysis of the available brands of domestic bottled water in Riyadh City, Saudi Arabia. Results indicated that more than 18 % of the sampled bottled waters exceeded the allowable limits for drinking water.

Alfadul and Khan, 2011 studied water quality of bottled water in the kingdom of Saudi Arabia: A comparative study with Riyadh municipal and Zamzam water. The results of the analysis were compared with the drinking water standards set by different regulatory agencies.

Rosborg, *et al*.2005 This study presents the concentrations of about 50 metals and ions in 33 different brands of bottled waters on the Swedish market. The levels of potentially toxic metals in the studied brands were generally low. Chinedu, *etal*.2011 water points in Canaanland, Ota, and nearby Iju River were analyzed for biological and physicochemical properties including heavy metal content.

Toma, 2013 shows a quality assessment of some bottled water that available in Erbil city, Iraq by using water quality index for drinking purposes. Using the water quality index all the bottled samples were classified as excellent to good water they are suitable for drinking purposes except Vauban bottled water which was bad and unsuitable for drinking. Tsakiris .2016 studied a new water quality index for bottled water assessment. The BWQI is a useful and easy to apply tool which can be used to evaluate the quality of bottled water based on its characteristics, obtained either from laboratory analyses or its label. Varrica, *et al*. 2013 analyzed sixteen bottled water of various Sicilian brands, 11 natural mineral waters and five normal drinking waters. Several considerations indicate that there is no sufficient reason to prefer bottled water to tap water.

Chapter Three

3. Materials and Methods:

3.1. Physical analysis:

3.1.1. Hydrogen ion concentration (pH):

It was measured directly in the field by Electrometric method using a portable pH-meter model (HANNA instrument, Portugal). The instrument was calibrated before each sampling using buffer solutions of (pH=4, 7and9) as described by A.P.H.A. (2012).

3.1.2. Electrical Conductivity (EC):

It was measured in the field using a portable conductivity meter model (HI 9811, HANNA instruments, 2000) calibrated with (0.01M) potassium chloride solution before each sampling, the results were expressed in $\mu S.cm^{-1}$ as described by (A.P.H.A., 2012).

3.1.3. Total Dissolved Solids (TDS):

Measured in the field using a portable TDS-meter model (HI9811, HANNA instruments, 2000), the results were expressed in mg l^{-1}. (A.P.H.A., 2012).

3.2. Chemical analysis:

3.2.1. Total Alkalinity:

It was determined in the laboratory by Titration method recommended by A.P.H.A. (2012), the results were expressed in mg $CaCO_3$ l^{-1} using the formula bellow:

Alkalinityas$mgCaCO_3$ l^{-1} =A*B*50000/ml of sample.

Where: A= ml of standard acid titrant. B= normality of standard acid.

3.2.2. Total Acidity:

Acidity was determined by titration method as described by A.P.H.A. (2012), the results were expressed in mg $CaCO_3$ l^{-1} using the following formula:

Acidityas$mgCaCO_3$ l^{-1} =A*B*50000/ml of sample.

Where: A=ml of standard NaOH titrant used. B= normality of standard NaOH.

3.2.3. Total Hardness:

It was determined by EDTA titrimetric method as described by A.P.H.A. (2012), using Erichrom Black T as indicator and buffer solution of pH 10, the results were expressed in mg$CaCO_3$ l^{-1} using the formula bellow: Hardnessas mg$CaCO_3$ l^{-1} =A*B*1000/ml of sample.

Where: A=ml titration for sample. B=mg$CaCO_3$equivalentto 1ml EDTA titrant.

3.2.4. Chloride (Cl^-):

It was determined by Argentometric method using silver nitrate titrantas described by A.P.H.A. (2012), the results were expressed in mg Cl^- l^{-1} by equation: mgCl l^{-1}=(A-B)*N*35450/ml of sample.

Where: A= ml titration for sample. B= ml titration for blank. N=normalityof$AgNO_3$.

3.2.5. Nitrite (NO_2): Determined by Spectrophotometric method according to Beendischnider and Robinson (1952) as described by Parsons,*et. al* (1984) using wavelength of 543nm in 1cm cauvatt cell using spectrophotometer model (PYEUNICAM SP 6.550, England), the results were expressed in µg-atN-NO_2l^{-1}.

3.2.6. Nitrate (NO_3):

Determined by Spectrophotometric method according to Beendischnider and Robinson (1952) as described by Parsons, *et. al* (1984) using wavelength of 543nm in 1cm cauvatt cell using spectrophotometer model (PYEUNICAM SP 6.550, England), the results were expressed in µg-atN-NO_2l^{-1}.

3.2.7. Reactive Phosphorus (PO_4^{-3}):

The procedure used (Ascorbic acid reduction method) was that of Murphy and Riley (1962), as described by Parsons,*et. al* (1984). The absorbance was measured in 1cm cauvatt cell at the wavelength 885nm, the results were expressed in µg-atP-PO4l^{-1}.

Chapter Four

4.Results and Discussions

The physico-chemical composition of analyzed Erbil bottled waters is summarized in Tables 1, figures 1 to 10. pH is a measure of the activity of Hydrogen ions (H^+) in a solution therefore, solution is either acidic (pH less than 7) or alkaline (pH greater than 7), according to WHO and Iraqi Standards for drinking bottled water, acceptable pH value ranges (6.5 – 8.5), accordingly, all studied bottled water brands available commercially in Erbil city, their values do not exceed the allowable limits, as shown in Fig.1. On the other hand, all pH values were on the right side of neutrality with pH values above 7 except Mira bottled water with value of 6.70. All brands pH value were between 6.70 and 7.60. Because all brands were from Iraqi Kurdistan Region inland waters which characterized by high pH values lies on the alkaline side of neutrality.

Table 1: Physico-chemical components of fifteen bottled water brands in Erbil city. Jan. 2024.

Brands	pH	EC µS cm^{-1}	TDS mg/l	Cl^- mg/l	Alk. mg/l	Acid. mg/l	Hard. mg/l	NO_2 mg/l	NO_3 mg/l	PO_4 mg/l
Aljoud	7.07	**38.00**	**19.00**	4.96	20.00	4.00	8.00	0.389	0.250	0.350
Alwaha	7.12	189.00	94.00	7.94	**8.00**	**10.00**	25.00	0.381	0.145	0.295
Aquafina	7.10	197.00	97.00	**1.99**	8.50	**2.00**	30.00	0.376	0.190	0.460
Ballak	7.40	239.00	119.00	7.94	9.00	2.50	16.00	0.436	0.685	0.290
Crystal	**7.60**	143.00	70.00	34.74	14.00	9.00	12.00	0.368	1.165	**0.240**
Hawler	**7.60**	186.00	93.00	27.79	52.00	4.00	27.00	0.363	1.240	0.250
Kani	7.30	202.00	101.00	35.73	**60.00**	**2.00**	29.00	0.363	0.280	0.255
Lava	7.50	181.00	90.00	19.85	32.00	4.00	27.50	0.408	0.190	0.340
Life	7.20	153.00	77.00	25.81	36.00	5.00	24.00	0.611	**0.100**	0.250
Massafi	7.50	167.00	83.00	**39.70**	44.00	3.00	30.00	0.598	1.120	**0.815**
Mira	**6.70**	**246.00**	**123.00**	18.86	10.00	5.00	**5.00**	**0.911**	0.580	0.260
Rovian	7.54	180.00	90.00	29.78	56.00	3.00	27.00	**0.345**	1.120	0.375
Slemani	7.30	160.00	80.00	31.76	48.00	4.00	30.00	0.436	0.415	0.570
Sulav	**7.60**	182.00	91.00	21.84	56.00	5.00	31.00	0.363	**1.585**	0.570
Tyian	7.10	223.00	111.00	9.93	38.00	4.00	**35.00**	0.376	0.235	0.280
Minimum	**6.70**	**38.00**	**19.00**	**1.99**	**8.00**	**2.00**	**5.00**	**0.345**	**0.100**	**0.240**
Maximum	**7.60**	**246.00**	**123.00**	**39.70**	**60.00**	**10.00**	**35.00**	**0.911**	**1.585**	**0.815**
Mean	**7.31**	**179.07**	**89.20**	**21.24**	**31.47**	**4.27**	**23.77**	**0.45**	**0.62**	**0.37**

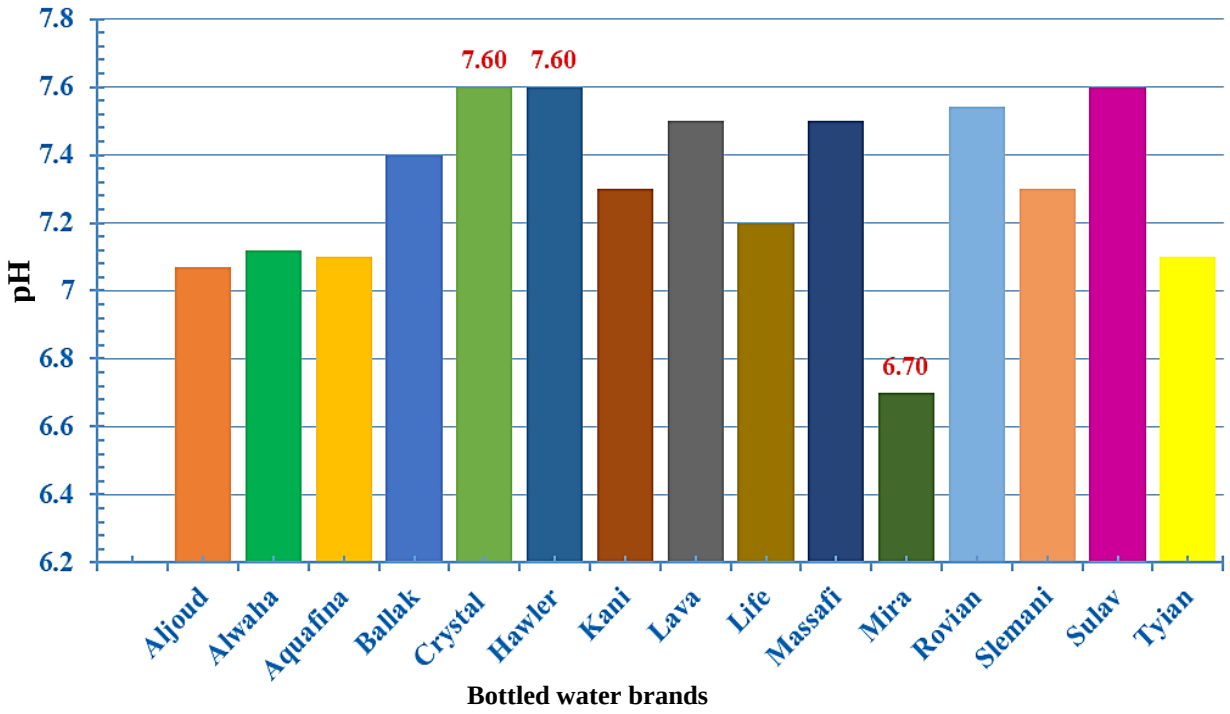

Figure 1: pH values of fifteen bottled water brands available in Erbil city.

Electrical Conductivity (EC) is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentrations, mobility, and on the temperature of measurement (APHA, 2012). Electrical conductivity EC results (Table 1 and Figure 2) showed that Mira, Ballak and Tiyan brands characterized by high levels of EC and it was 246, 239 and 223 µS cm^{-1} respectively. While Aljoud water has the lowest EC value of 38 µS cm^{-1} among the studied samples. The rest of the brands were with EC values between 100 and 200 µS cm^{-1}. All studied bottled water brands were within the maximum permission level (500 µS cm^{-1}). In the same fashion, Total dissolved solids TDS (Table 1 and Figure 3) Mira, Ballak and Tiyan brands characterized by high levels of TDS and it was 123, 119 and 111 mg/l respectively. Whereas, Aljoud water was with the lowest TDS value of 19 mg/l. All fifteen studied brands were remained within the limits proposed by (IQS, 2001 and WHO, 2017).

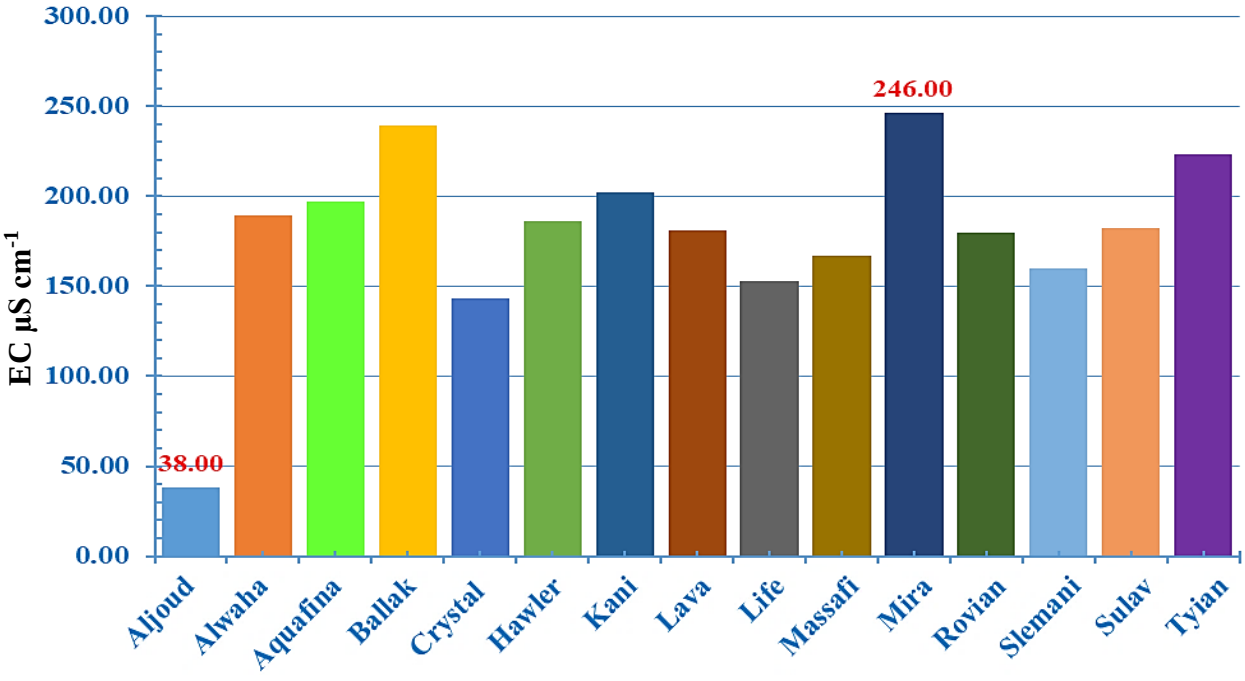

Figure 2: EC values of fifteen bottled water brands available in Erbil city.

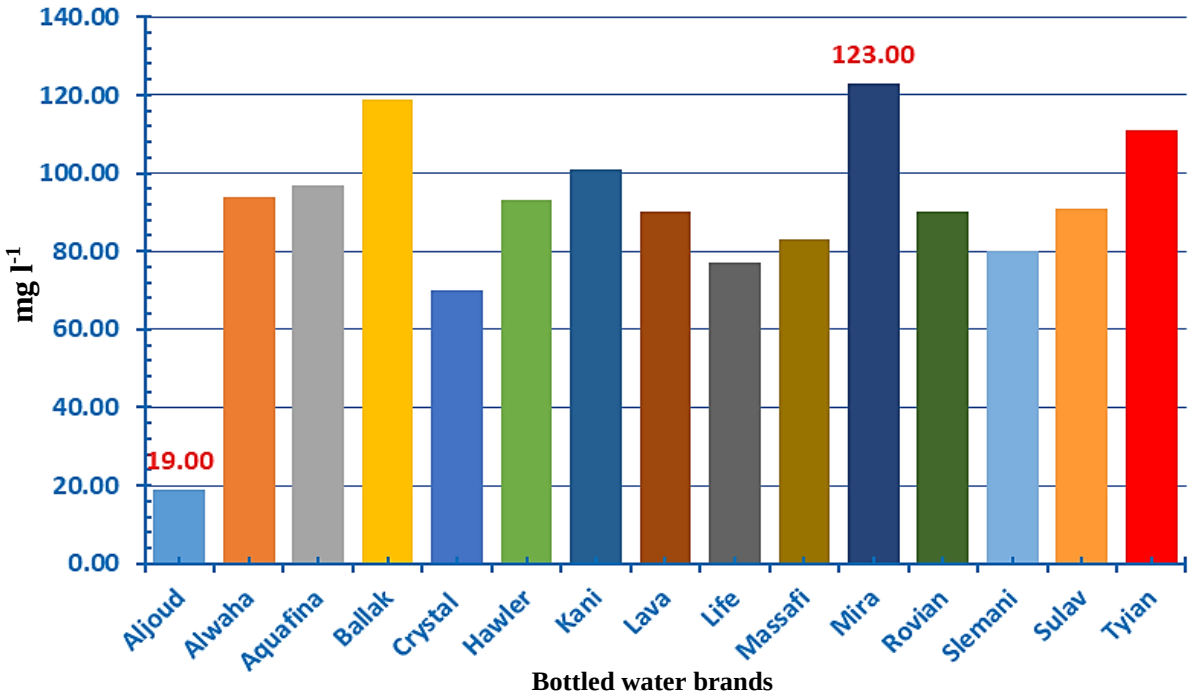

Figure 3: TDS values of fifteen bottled water brands available in Erbil city.

Chloride (Cl^-) is widely distributed in nature, generally from sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$) salts, and the presence of chloride in natural waters can be attributed to dissolution of salt deposits (WHO, 2017). Chloride ion concentration (Table 1 and Figure 4) ranged between 1.99 and 39.70 mg/l in Aquafina and Massafi bottled water brands respectively. Bottled water brands Aquafina, Aljoud, Alwaha and Ballak characterized by low levels of chloride while Crystal, Kani and Massafi contain high levels of chloride. All studied bottled water brands were within the maximum permission level of (250 mg/l) as proposed by (IQS, 2001 and WHO, 2017).

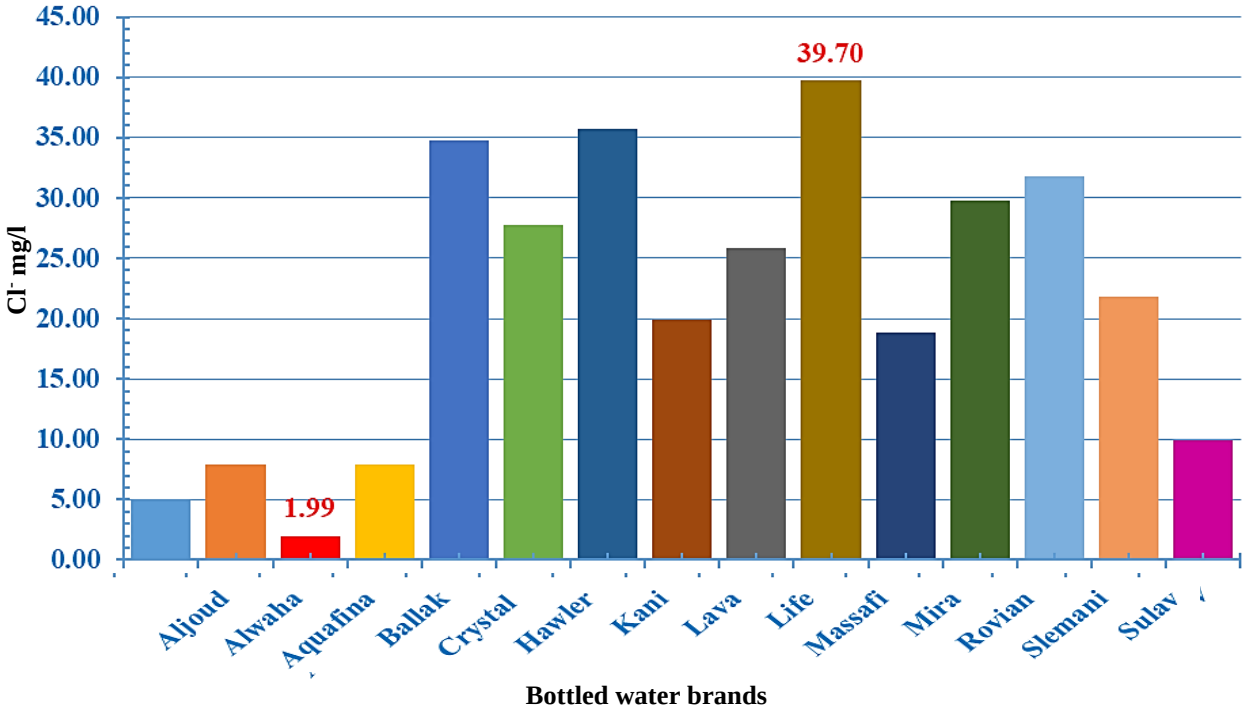

Figure 4: Chloride-Cl^- values of fifteen bottled water brands available in Erbil city.

The alkalinity of water is its capacity to neutralize acid, the amount of a strong acid needed to neutralize the alkalinity called the total alkalinity (Batram and Ballance, 1996). Alkalinity results (Table 1 and Figure, 5) revealed that the value ranged from 8 to 60 mg/l in Alwaha and Kani respectively. Alwaha, Aquafina, Ballak and Mira characterized by low levels of Alkalinity while Hawler, Kani, Rovian and Sulav contain high levels of Alkalinity. Acidity of water is its quantitative capacity to react with a strong base to a designated pH (APHA, 2012). Acidity (Table 1 and Figure 6) ranged from 2 in Aquafina and Kani to 10 mg/l in Alwaha bottled water brands.

Results revealed that all bottled water brands characterized by alkalinity and acidity values below maximum permission level of (250 mg/l).

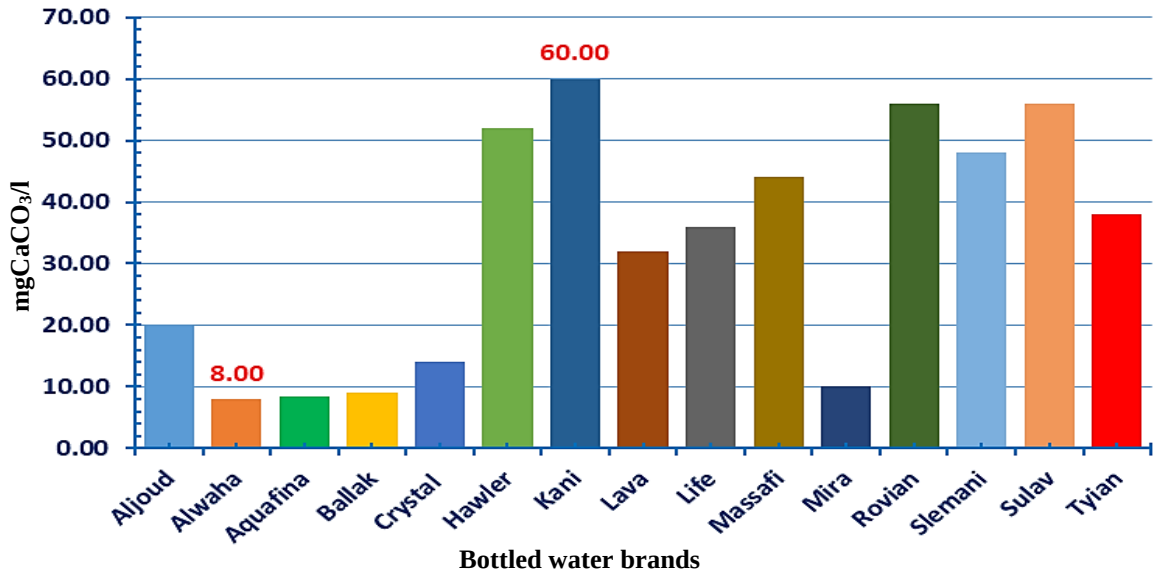

Figure 5: Alkalinity values of fifteen bottled water brands available in Erbil city.

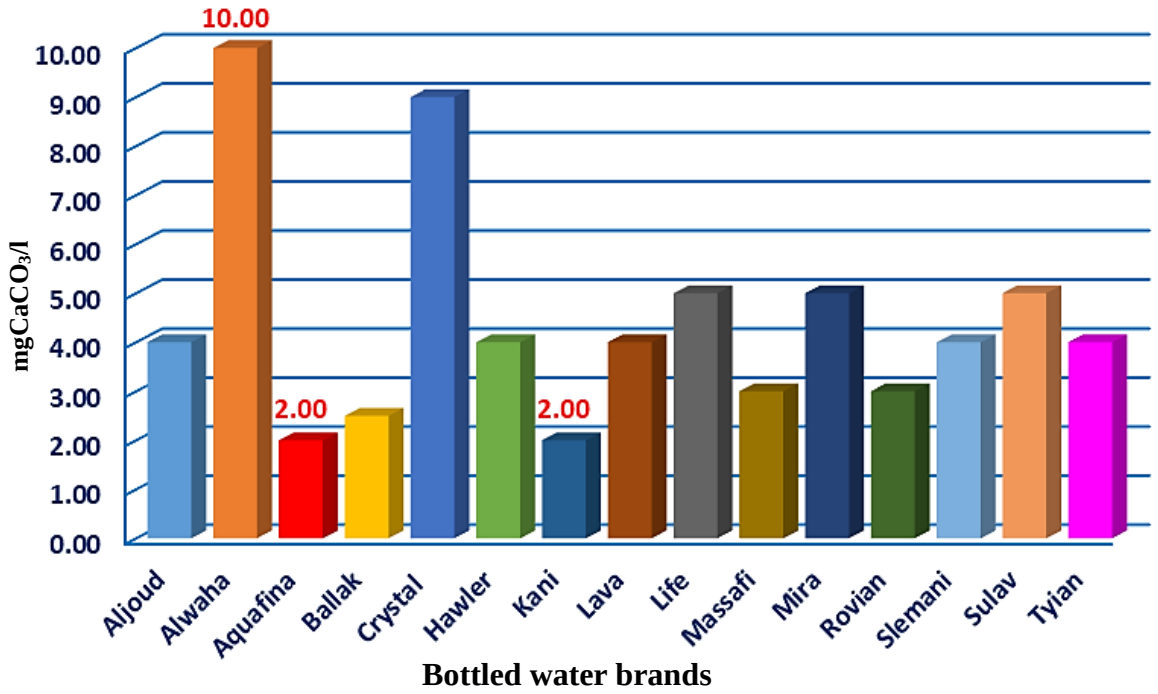

Figure 6: Acidity values of thirteen bottled water brands available in Erbil city.

On the other hand, Total hardness (Table 1 and Figure 7) ranged from 5 mg/l in Mira to 35 mg/l in Tiyan brand. In fresh water, the principle hardness – causing ions are calcium and magnesium, originated from the sedimentary rocks, the most common being limestone and chalk (WHO, 2017). All studied bottled water brands remained in safe levels of 250 mg/l during the studied period.

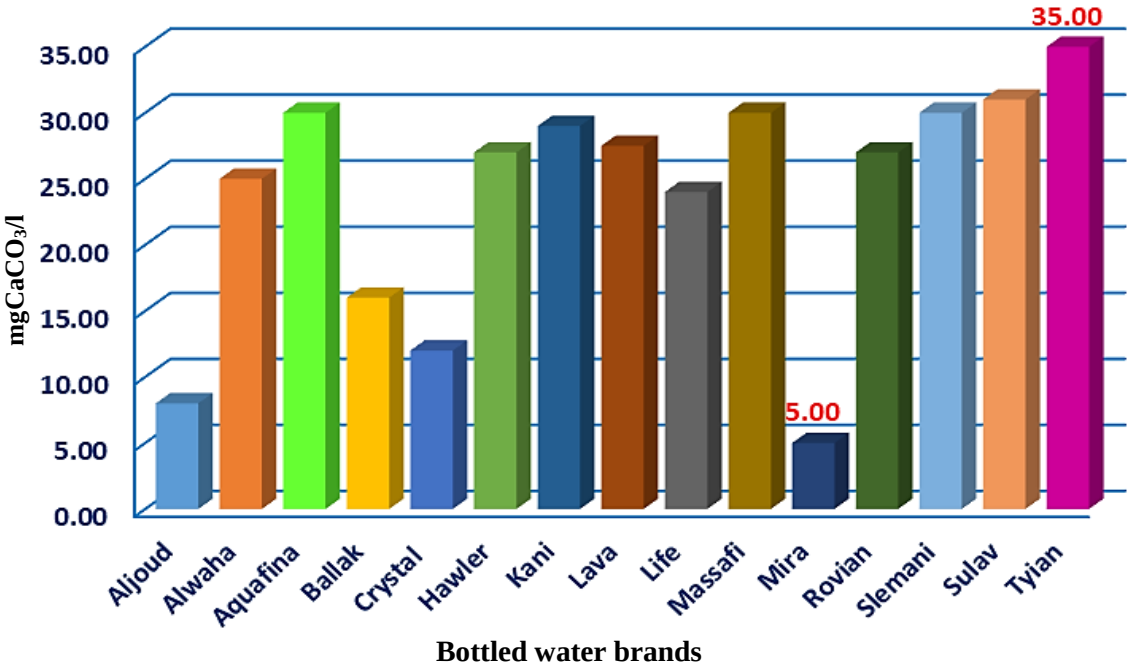

Figure 7: Hardness values of thirteen bottled water brands available in Erbil city.

Nitrite (NO_2) considered as an indicator of pollution in water when present in concentrations more than 1 mgl^{-1} as nitrite (WHO, 2017), however the concentration of nitrite in natural water s were low because its unstable form of nitrogen and immediately oxidized to nitrate or reduced to ammonia (Goldman and Horne, 1983). Nitrite concentration ranged from 0.34 to 0.91 mg/l in Rovian and Mira brands respectively. It is worth to mention that Mira bottled water was close to maximum permission level of 1 mg/l, while the others were far below limits proposed by (IQS, 2001 and WHO, 2017). Nitrate (NO_2) considered as an indicator of pollution in water when present in concentrations more than 10 mgl^{-1} as nitrate (WHO, 2017), Nitrate concentration ranged from 0.1 to 1.59 mg/l in Sulav and Life brands respectively. Generally, Life, Alwaha and Lava characterized by low levels of nitrate while Sulav, Crystal, Hawler, Massafi and Rovian contain high concentration of nitrate. All studied bottled water brands were below the maximum permission level of 10 mg/l proposed by (IQS, 2001 and WHO, 2017).

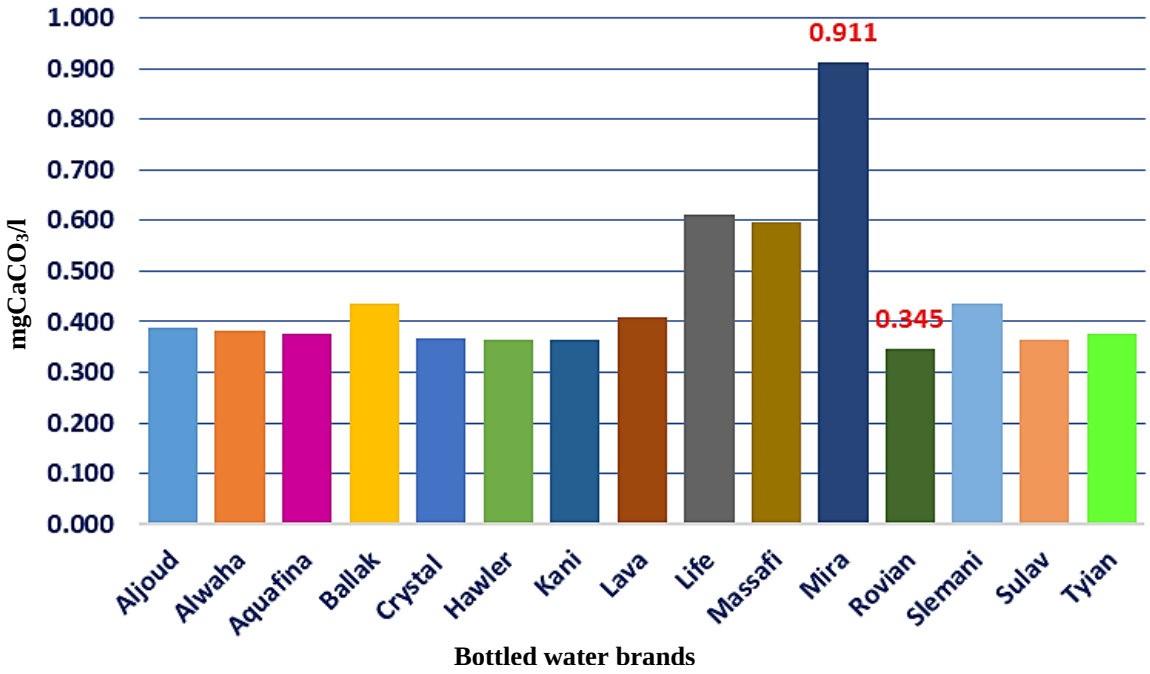

Figure 8: Nitrite-NO_2^- values of fifteen bottled water brands available in Erbil city.

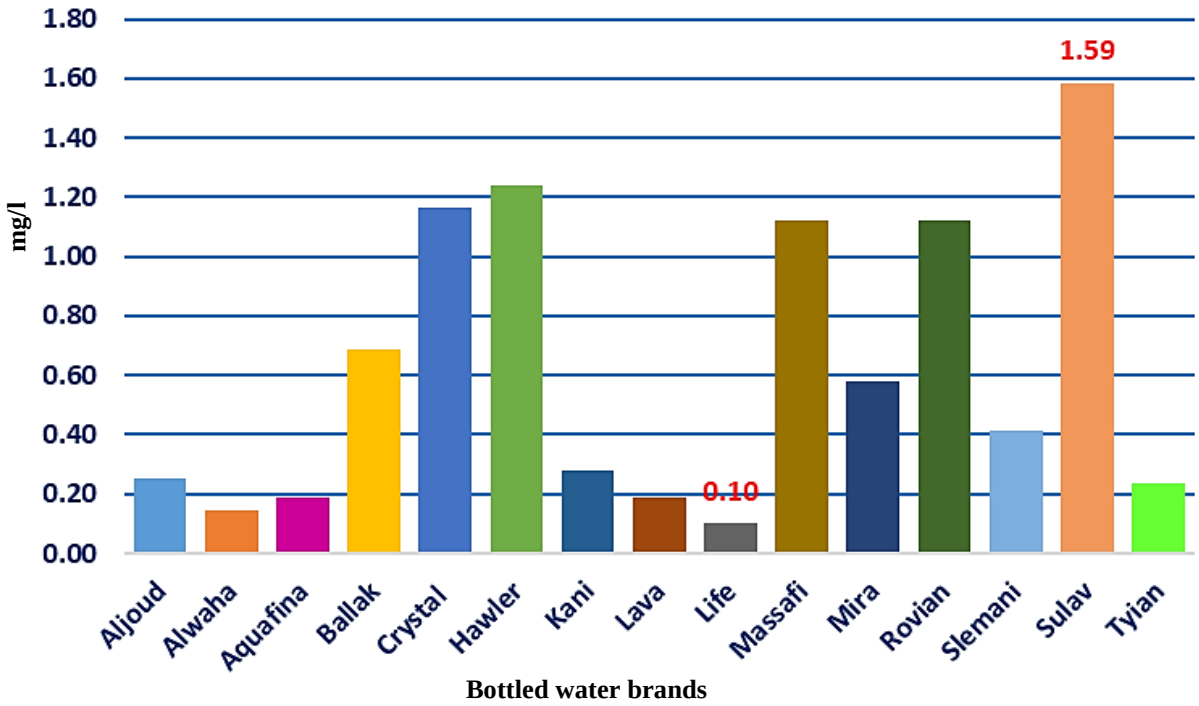

Figure 9: Nitrate-NO_3^- values of fifteen bottled water brands available in Erbil city.

Phosphorus (PO_4^{-3}) is a major nutrient required for normal growth of all living cells, its essential for almost all cellular processes, i.e. biosynthesis of nucleic acids. The phosphate concentration ranged between 0.24 to 0.82 mg/l in Crystal and Massafi brands respectively. Crystal, Hawler, Kani, Life and Mira characterized by low levels of phosphate, whereas, Massafi, Aquafina, Slemani and Tiyan were contain high levels of phosphate. Generally all studied bottled water brands were safe to drink because they contain phosphate levels less than 1 mg/l.

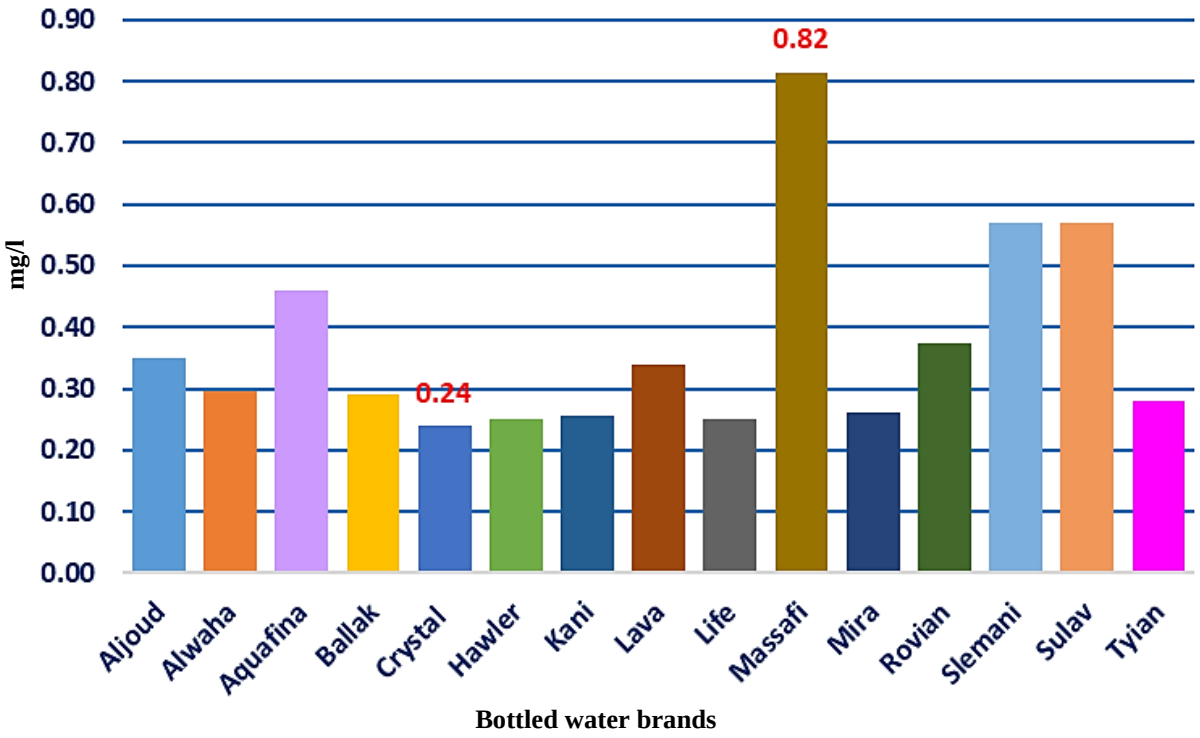

Figure 10: Phosphate-PO_4^{3-} values of fifteen bottled water brands available in Erbil city.

Conclusions and Recommendations

1. All studied brands were with pH, EC and TDS values not exceeded the allowable limits.
2. Sulav, Rovian, Hawler and Crystal bottled water brands characterized by high levels inorganic components as nitrogen-nitrate, while Alwaha, Aquafina and Lava has the lowest components among the studied brands.
3. All studied brands contain low concentrations of nitrate except Mira brand.
4. Low concentrations of phosphate were detected in all brands except Massafi brand.
5. Massafi, Slemani, Sulav and Tiyan characterized as moderately hard water.
6. All studied bottled water brands are safe for drinking.
7. Further analyses are required for heavy metal levels and bacteriological studies.
8. Further analyses are required for the effect of time and temperature on water quality.

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