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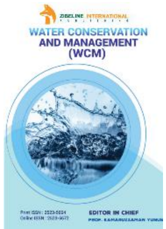

RESEARCH ARTICLE

BOTTLED WATER SOLD IN THE TRIPOLI MARKETS: CHALLENGES AND SHORTCOMINGS

Reda Fhelboom[a] and Bashir Brika[b*]

[a]Department of Chemical Engineering, Faculty of Gas and Oil Engineering, Al-Zawia University, Al-Zawia, Libya
[b]Advanced Laboratory of Chemical Analysis, Authority of Natural Science Research and Technology, Tripoli, Libya
**Corresponding Author e-mail: bashirforlibya@gmail.com*

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ABSTRACT

Bottles of water, by different trademarks which lack of the standard specifications, have overwhelmed shops and markets in Libya. Despite the fact that the number of plants and factories of bottled water is increasing rapidly, there has not been any serious intention on the part of governmental bodies to take action against the unlicensed factories. This has led to the quality of bottled water in many cases violating the required standards of chemical and physical properties for the potable water, which threatens the public health. The aim of this paper was first, to investigate whether if these bottled water do really meets the international and Libyan standards of bottled water, and second to point out the actions taken by the responsible authorities as well as other related governmental/non-governmental organizations. The paper examined four random samples of bottled water sold in Tripoli during January 2019 and measured some of its physicochemical properties, such as total dissolved solids (TDS), pH, sodium, potassium and calcium. The results indicated that all the experimental values were different from what was written on the samples' labels. The percentage of these differences ranged from 2% to 650 %. The statistical data of TDS (labeled-measured) was found to be 78.725 mg/l with a standard deviation of 33.91758 mg/l, and t-test with $p = 0.019$ ($P \leq 0.05$), which means results are significant. It was also observed that all samples violated the Libyan standards in not providing all the required data on their labels; 25% of samples do not include water source, 50% of samples do not mention the source of the water, 75% of samples do not mention license number, and 50% of samples do not provide any written statement regarding the storage conditions, which means that all the samples must be withdrawn from the market without the need for chemical or biological testing.

KEYWORDS

bottled water, drinking water quality, Libyan standards for bottled water.

1. INTRODUCTION

Socio-economic development in urban and rural areas in recent decades, coupled with an increase in water consumption rates, has created an urgent need for drastic changes in water treatment technologies, often due to the severe shortage of potable water in many countries, or as a result of polluted water sources in many developing countries. This has led to the emergence of what is known as bottled water. Bottled water is drinking water sealed in bottles with no added ingredients except that, like tap water, it may contain safe and suitable antimicrobial agents. Fluoride may be added within limitations set in the bottled water quality standards (this varies between countries) (Parag et al., 2011). Bottled water is currently, circulating alongside other food products in the markets in both developed and developing countries, including Libya, and its consumptions is increasing rapidly because it is handy and easy to carry, and people believe that it is pure and safe for drinking. National and international organizations have set standards and specifications that determine the required quality of bottled water, and that any manipulation of these specifications could lead to health problems for the consumers, who are increasing daily, due to the lack of tap water or the deterioration of its quality.

Different types of bottled water differ from each other in the treatment method, chemical composition and water source, and bottled water can be classified as: 1- Mineral water: which is the water extracted from groundwater and contains fixed proportions of minerals and trace elements, a natural mineral water that is not chemically treated nor polluted; 2- Purified water: which is produced through a distillation or desalination process; 3- Sparkling water: which natural mineral water which is characterized by its content of carbon dioxide.

Recent decades have witnessed a rising global consumption of bottled water, especially in developed countries where water directly from the tap is drinkable. Italy is considered to be the largest producer and consumer of bottled water in the world, producing 496 types of bottled water trademarks, followed by Germany, which produces 425 bottled water trademarks. Globally, the total consumption of bottled water topped 329.33 billion L in 2015, an increase of more than 1/3 in per capita terms over a span of five years (Rodwan, 2015). A recent report found that a million plastic bottles are purchased every minute around the world, with that figure likely to increase another 20% by 2021 (A Million Bottles a Minute, 2017).

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Excessive groundwater exploitation, decreased annual average of rainfall, intensive agricultural activities in the coastal plains and seawater intrusion were the main causes of the shortage of clean and fresh water in Libya, especially in the coastal regions (Brika, 2019). Therefore, there was a need for the government to allow establishment of many factories/plants to treat, purify and produce water. The production of bottled water in Libya began in 1959 with the establishment of the Bin Gheshir water plant.

By law, bottled water in Libya should comply with the Libyan Standards of bottled water (LNS 10:2016). However, to satisfy the local need for bottled water and because of economic interests, numerous bottled water suppliers have increased significantly in the Libyan market, many of which do not have any registration or approved license from public health authorities. In the absence of official registries, it is difficult to estimate the exact numbers of bottled water brands in Libya, yet the majority operates without any regulatory authorization. On the other hand, the Tripoli's Food and Drug Control Center has estimated the number of bottled water brands in the western part of Libya to be more than 100, while most of the factories are not licensed (Personal communication with Dr. Samir Al-Ghul, 2019). The products of these plants are becoming widely available in the Libyan shops and markets today.

During the past decade, there has been a considerable increase in the household consumption of bottled water in Libya, especially in the summer. Bottled water consumption was the first reported water source with 43.2% of households overall. Following this, 37.8% of households reported relying on an improved, safely managed public network as their main source of drinking water. The use of private protected wells was the third main source reported by 11.9% of households. In Tripoli, the majority of households (61.2%) indicated that they rely on bottled water as their main source of water due to instability in the main water network following recent maintenance work (REACH, 2017). The water network supply could be deliberately cut off for long periods of time when armed groups controlled it in a struggle for influence over an area in the city (Lewis et al., 2017). In addition, the quality of Tripoli tap water supplied by the man-made river project (MMRP) is also questionable as some cases of high content of nitrate and bacterial contamination have been reported in the past. Therefore, the quality of water supplied by MMRP needs to be studied intensively in the near future.

The main source of bottled water sold in Tripoli is pumped from drilled wells via a reverse osmosis desalination process.

Although numerous studies were conducted to assess bottled water quality in other countries, very few studies were conducted in Libya, and on selected bottled water brands and for few parameters only. Furthermore, there is no comprehensive study has been conducted to determine how safe the brands of bottled water marketed in the capitol Tripoli are for the consumers.

In the present study, the chemical and physical characteristics of four domestic brands of bottled water sold in Tripoli market were investigated and the accuracy and precision regarding the levels reported on the manufacturers' labels questioned. Also, the results were compared with the proposed regulation regarding bottled water in Libya [Table 1]. As a part of the study, face to face interviews were done with some governmental authorities' representatives, including the ministry of Local Government for Technical Affairs, municipality of Tripoli and The Libyan National Center for Standardization and Metrology.

Table 1: Present regulations and standards for the bottled drinking water

Chemical element	Maximum allowed concentration (mg/l)			
	WHO (2018)	EPA (2002)	Current Libyan Standards (2008)	Proposed Libyan Standards (2016)
Arsenic (As)	0.01	0.01	0.01	0.01
Barium (Ba^{2+})	0.7	2	0.7	0.7
Beryllium (Be)	-	0.004	0.001	0.001
Cadmium (Cd^{2+})	0.003	0.005	0.003	0.003
Calcium (Ca^{2+})	-	-	-	-
Chloride (Cl^-)	-	250	150	250
Chromium (Cr)	0.05	0.1	0.05	0.05
Copper (Cu)	2	1.3	1.0	1.0
Fluoride (F^-)	1.5	2	1	1.5
Iron (Fe)	-	0.3	0.3	0.3
Lead (Pb)	0.01	0.015	0.01	0.01
Magnesium (Mg^{2+})	-	-	-	75
Manganese (Mn^{2+})	-	0.05	0.01	0.05
Mercury (Hg)	0.006	0.002	0.001	0.01
Nitrate ($NO3^-$)	50	44	10	45
Nitrite ($NO2^-$)	3	3.3	0.02	3
Potassium (K^+)	-	-	12	12
Sodium (Na^+)	-	-	100	200
Sulfate ($SO4^{2-}$)	-	250	150	250
TDS	-	500	500	100-500
Turbidity NTU	-	1	1	5
pH	-	6.5–8.5	6.5–8.5	6.5-8.5

WHO - World Health Organization, EPA - US Environmental Protection Agency

Table 2: Chemical and physical elements of bottled waters in comparison of the elements labeled on the bottles

Indicator	Brand								Libyan Standards (mg/l)	Error %
	A		B		C		D			
	Measured	Labeled	Measured	Labeled	Measured	Labeled	Measured	Labeled		
Total Hardness	-	200	-	NW	-	NW	-	8.42	200	-
pH	7.28	6.5-7.5	7.45	7.0	7.16	7.2-7.8	6.92	6.74	6.5. – 8.5	-
TDS	75.3	120	89.9	≤200	44.4	≤150	45.5	≤100	≤ 500	37.3
Sodium	25.5	16	34.8	52.9	13.6	NW	14.2	13	100	9 - 56
Potassium	0.3	1.0	0.1	0.2	0	NW	0	1.0	12	50 - 100
Calcium	7	8.0	7.5	1.0	4.2	NW	5.5	1.2	-	12 - 650
Bicarbonate	-	25	-	18.3	-	NW	-	16	150	-
Sulfate	-	15	-	9.6	-	NW	-	6	150	-

W= Written, NW=Not Written, NA= Not Applicable

2. Materials and Methods

2.1 Water samples

In this study, 4 bottled water samples (named A, B, C and D) of brands produced locally and distributed all over Tripoli and its suburbs were collected randomly from supermarkets in Tripoli in the winter of 2019. These were considered to be the most consumed brands with very high sales. The selected bottled water did not contain added gas and were purchased in the 0.5 L polyethylene terephthalate (PET) bottles. The four samples were desalinated brackish water.

2.2 Chemical and physical analysis

The bottled water samples were all opened and analyzed at the water quality laboratory of the Advanced Laboratory of Chemical Analysis, Tajoura, Tripoli, where they were examined for some chemical and physical properties which could be tested at the local laboratory. The pH, total dissolved solids (TDS), calcium, sodium and potassium were tested as chemical and physical indicators for the water quality.

3. Results and Discussion

The results of the chemical and physical analysis of the bottled water samples compared with the constituents reported on bottle labels and the Libyan standards of drinking water are shown in Table 2 and Table 3.

The average labeled pH value for the drinking bottled water samples was 7.06 while the average measured pH value was 7.2025 with a standard deviation of 0.19292162. The average error between the measured and labeled data was just 2% which is in the safe limits of the error. The standard value for measured pH has a range of 6.5 to 8.5 based on the Libyan Standards of drinking water (No 10/2008). WHO did not establish a range for pH values, as it usually has no direct impact on consumers at levels found in drinking-water. It is however, an important operational parameter, and the Guidelines for Drinking-water Quality (GDWQ) indicate an optimum pH range of 6.5-8.5 (World Health Organization, 2018).

Concerning the total dissolved solids (TDS) which is considered a very important indicator for the quality of drinking water, results showed that measured TDS in all samples was less than 100 mg/l with an average of 63.775 mg/l and a standard deviation of 22.544 which is within the current Libyan standards but less than the minimum limit of some international standards. Additionally, the absence of the minimum required concentration of some chemical components necessary for drinking water in the Libyan standards is considered to be one of the main shortcomings of the current standards.

Huge efforts, including lots of scientific discussion regarding this particular failure in the current Libyan standard for the quality of drinking water, led the Libyan National Center for Standardization and Metrology to update the current specifications [LNS 10:2016]. The new draft of the updated Libyan standards for bottled water still needs to be confirmed and authorized by the responsible authorities. It was also very clear that the value of average measured TDS was very different from the labeled value by 55.3%.

According to the medical science, the lower level of minerals in water has no benefits for thirsty and malnourished people. In Libya, most of the people don't know the benefits of dissolved minerals for maintaining their good health. On the other hand, there are no known documented experiences which show that consuming low TDS water will create any long-term health effects. The US Navy has used distilled sea water for human consumption for approximately 40 years (Manual of Naval Preventative Medicine, 2005). TDS levels below 3 mg/L have been reported and consumption of this water for months at a time is common on submarines. No health problems have been reported by the Navy.

The value of measured sodium in samples ranged between 13.6 and 34.8 mg/l with an average of 22.025 mg/l and standard deviation 101.24. The average of labeled sodium in samples was found to be 142.50 mg/l with an average error between the labeled and measured of 55.3% which means the labels on samples do not reflect reality. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/l and no health-based guideline value has been set by WHO (World Health Organization, 2011).

The value of measured Potassium in samples ranged between 0 and 0.3 mg/l with an average of 0.01 mg/l and standard deviation 0.1414, which is very different from its limit in Libyan specification (12 mg/l). The difference between the labeled and measured data for potassium was about 86.3%, which is a very big difference. The value of measured Calcium in samples ranged between 4.2 and 7.5 mg/l with an average of. 6.05 mg/l and standard deviation 3.98497, and it differs from the labeled average value (3.4 mg/l) by 77.9%. The Libyan specification does not set any maximum or minimum limits for calcium; however, the WHO Guidelines for Drinking-water Quality (GDWQ) advise a taste threshold for calcium ion of 150 – 300 mg/l , as thirty-one countries specified a maximum value of 500 mg/l and 30 mg/l for minimum value for calcium in drinking water.

Recent studies suggest that the intake of soft water, i.e. water low in calcium, may be associated with higher risk of fracture in children, certain neurodegenerative diseases, pre-term birth and low weight at birth and some types of cancer. In addition to an increased risk of sudden death, the intake of water low in magnesium seems to be associated with a higher risk of motor neuronal disease, pregnancy disorders (so-called preeclampsia)), and some types of cancer (Frantisek, 2004).

The results showed that all the experimental values were different from what was written on the samples labels, while the percentage of error ranged from 2% to 650%.

4. Statistical Analysis

The results of just two indicators (TDS and PH) were analyzed by statistical method (t test) as the other three indicators had missing data on their labels (Sodium, Potassium and Calcium) and could not be calculated.

The mean of TDS (labeled-measured) was found to be 78.725 mg/l and standard deviation of 33.91758 mg/l, and t test with $p = 0.019$, which means a significant difference between the measured and labeled data for TDS.

The mean of pH (labeled–measured) was found to be -0.1425 with standard deviation of 0.3404 and t test with p value $p < 0.464$, which means no significant difference between the measured and labeled data.

5. Information of Bottles Labels

The written information on each bottle was also compared to the necessary information that Libyan Standards of drinking water (No 10/2008) required to be written on bottled water labels as shown in Table 3.

Table 3: Chemical and physical Statistical analysis of bottled water samples in comparison of the elements labeled on the bottles

Indicator		Brand								Libyan Standards	Ave Error %
		A	B	C	D	Ave	Min	Max	STDV		
pH	Measured	7.28	7.45	7.16	6.92	7.2025	6.92	7.45	0.2228	6.5 – 8.5	2
	Labeled	6.5-7.5	7	7.2-7.8	6.74	7.060	6.5	7	0.3179		
TDS	Measured	75.3	89.9	44.4	45.5	63.775	44.4	89.9	22.54409	≤500	55.3
	Labeled	120	≤200	≤150	≤100	142.50	100	200	43.49329		
Sodium	Measured	25.5	34.8	13.6	14.2	22.025	13.6	34.8	10.1240226	100	19
	Labeled	16	52.9	NW	13	27.3	13	52.9	22.2209361		
Potassium	Measured	0.3	0.1	0	0	0.1	0	0.3	0.14142136	12	86.3
	Labeled	1	0.2	NW	1	0.733333	0.2	1	0.46188022		
Calcium	Measured	7	7.5	4.2	5.5	6.05	4.2	7.5	1.49777613	NA	77.9
	Labeled	8	1	NW	1.2	3.4	1	8	3.98497177		

Table 4: Paired Samples Statistics

Indicator		Mean	N	Std. Deviation	Std. Error Mean
TDS mg/l	labeled	142.50	4	43.49329	21.74665
	measured	63.7750	4	22.54409	11.27204
pH	labeled	7.060	4	0.3179	0.1590
	measured	7.203	4	0.2228	0.1114

Table 5: Paired Samples Test

indicator	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TDS mg/l (labeled – measured)	78.72500	33.91758	16.95879	24.75456	132.69544	4.642	3	0.019
pH (labeled – measured)	-0.1425	0.3404	0.1702	-0.6842-	.3992	-0.837-	3	0.464

Results showed that 50% of the collected bottled water samples labels violated the Libyan standards by not having printed at least one of the basic components of the product written.

It was also observed that all samples violated the Libyan standards in not printing all the required data on their labels as shown in Table 6. Twenty-five percent of the samples do not include the water source, 50% of the samples do not mention the source of the water, 75% of the samples do not mention a license number, and 50% of the samples do not display any written statement regarding the storage conditions.

Table 6: The information should be written on bottled water samples' labels

Information	Samples				
	A	B	C	D	Percentage of non-written information
Water Source	W	W	NW	W	25%
Water source location	W	W	NW	NW	50%
Name and address of water plant	W	W	W	W	0%
License number	NW	W	NW	NW	75%
Bottle size	W	W	W	W	0%
Bottle should be kept in a well-ventilated place away from direct sunshine	W	NW	W	NW	50%
Bottle should be kept in away from pollution source	W	NW	W	NW	50%
Type of bottle and its cover	W	W	W	W	0%
Production and expiry date by day, month any year	W	W	W	W	0%
Water Treatment Type	W	W	W	W	0%
Percentage of non-written information	10%	20%	30%	40%	25%

The Food and Drug Control Center confirms that if the labeling is contravening the Libyan standard, the bottled water is considered to be non-conforming and contrary to the specification and must be withdrawn from the market without the need for chemical or biological testing.

6. Challenges

During this study, personal investigations were done by the authors in order to confirm whether or not the bottled drinking water factories had obtained the required licenses from the related governmental boards. The shocking answers were given by the Food and Drug Control Center, which is considered to be one of the main governmental boards related to the investigated issue, was that there is no solid data regarding names, numbers and production capacity of these factories. What makes this issue worse, is that most of the bottled water factories operating in Libya are not licensed.

Another challenging concern was experienced when questions regarding monitoring the quality of the bottled water were put to the Municipal Guard Dep. at Abu Salim Municipality in Tripoli and the Environmental Rectification Office. The shocking answer was that the office is unable to do the required analysis due to the absence of technical laboratories. Additionally, and due to the lack of financial capabilities, the office is currently unable to carry out its duties, as the only available water laboratory is now under control of another neighboring Municipality and it is closed for maintenance.

The Deputy Minister of Local Government for Technical Affairs, states that the Environmental Rectification Offices were transferred in 2013 from the Housing Ministry to the Local Governance Ministry and Municipality but the Housing Ministry still temporize the management transferfor financial interests, which leads in the end to these offices remaining out of service. But from the administrative point of view, there is still a delay by the Ministry of Housing and Utilities impeding the transfer of the sanitation file for several reasons, the most important of which is the wish of the Ministry of Housing to supervise the closure of some of the previous contracts. The mayor of Tripoli declares that there is no water laboratory in the municipality at the moment and there is no laboratory that can be relied on to analyze the water, but the municipality is in the process of preparing a lab for drinking water, which will be processed within months and through which the quality of drinking water will be monitored in the municipality. As a result, bottled water which does not meet the Libyan Standards will be prevented from entering the Libyan market.

On the other hand, there is a small operating water laboratory located in the municipality of Tajoura (14 km East of Tripoli) that provides water analysis (chemical and biological analysis) for both domestic and industrial purposes without any charge for the public and with certain fees for companies and factories. However, this laboratory cannot continue handling all the water analysis for a long period without securing the required raw materials for the analysis from somewhere. Therefore, doors are open for the municipality of Tripoli or any other private and/or governmental organizations to financially support the water laboratory in the city of Tajoura to purchase the raw materials and tools to keep the laboratory running till the previously mentioned new water Laboratory is operational.

Sales of the bottled water in Tripoli's shops represent a very important income for their owners. "30% of the daily sales of the shop comes from selling the bottled water", "we sell about four Libyan brands of bottled water, and the main criterium for their quality is the taste". These were the main statements made by some shop keepers when they were asked about the quality of bottled water sold in their shops. Some others went too far and stated that "they have no idea about the required drinking water standards". Based on these answers, it can be concluded that the most desired and sold bottled water in Tripoli markets are the ones that taste good, no matter if the Libyan drinking water standards are met or not. This conclusion may lead to a very serious impact on human health since the lack of very important chemical elements in bottled water is the case in most of the bottled water sold in the local markets. Drinking water with very low sodium, potassium, calcium or magnesium is more like drinking distilled water that does not contain the necessary minerals that benefit the human body, and over time could harm the person and could lead to heart disease, high blood pressure, cardiac arrest, premature aging and osteoporosis.

7. Conclusions and Recommendations

This paper aims at starting a discussion in Libya about the importance of bottled water quality and the right of the consumers to buy a safe and healthy product with contents clearly labeled on the bottle.

The results indicated that all measured chemical parameters of water samples analyzed in this study were within the acceptable range of the Libyan standards. On the other hand, there were differences between concentration of these chemical parameters and label information on the bottles.

It was also observed that the current labelling of some analyzed bottled water samples lacks information about the water source location, License number and storage conditions.

Despite the fact all the measured chemical elements were within the Libyan standards limits, bottled water has very low contents of sodium, potassium and calcium. Thus, the human body can be affected over time.

Protecting water quality, providing and maintaining safe drinking water and sanitation services is a shared responsibility of government, the private sector and civil organizations to improve the quality of life.

More chemical evaluation on produced bottled water in Tripoli and other cities in Libya is recommended. The microbiological quality of packaged drinking water marketed in Libya is also recommended for intensive investigation.

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