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Assessment of some physical and chemical properties of the group of locally bottled drinking water brands sold in the markets in Mukalla city- Yemen

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Abstract:

This study aimed to determine some physical and chemical properties of some locally made types of bottled drinking water circulating in the markets in Mukalla and compare them with the Yemeni standard specifications. 18 random samples of bottled drinking water from different companies were randomly selected during the period from December 2020 to June 2021 from markets in the city. The samples were kept in a cool, well-ventilated place and away from sunlight until the time of analysis. Analyzes were carried out to determine: Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}), TDS, and pH. The samples were investigated in laboratory at the Faculty of Environmental Sciences and Marine Biology, Hadhramout University, by known scientific methods. The Yemeni national standards were adopted as a standard to assess the samples. The results showed that the concentration of: Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, TDS and pH in all samples did not exceed the maximum limits set by Yemeni standards. Regarding Na^{+} and K^{+}, the results showed that 89% of the Na^{+} samples and 94% of the K^{+} samples failed to meet the Yemeni standards, and this may lead to long-term health risks for humans. This study concluded with presenting of some recommendations and proposals that would improve and develop the bottled drinking water industry.

Keywords: Bottled drinking water, Water properties, Yemeni standards, Mukalla, Yemen.

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تقييم بعض الخصائص الفيزيائية والكيميائية لمجموعة من ماركات مياه الشرب المعبأة محلياً والمباعة في أسواق مدينة المكلا – اليمن

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هدفت هذه الدراسة إلى تحديد بعض الخواص الفيزيائية والكيميائية لبعض أنواع مياه الشرب المعبأة المصنعة محلياً والمتداولة في أسواق مدينة المكلا ومقارنتها بالمواصفات القياسية اليمنية. أُختيرت 18 عينة عشوائية من مياه الشرب المعبأة من شركات مختلفة خلال الفترة من ديسمبر 2020 وحتى يونيو 2021، من أسواق المدينة، حيث حفظت العينات في مكان بارد وجيد التهوية وبعيدا عن أشعة الشمس حتى وقت التحليل. أُجريت التحاليل لتحديد: الكالسيوم(Ca^{2+})، المغنيسيوم(Mg^{2+}) الصوديوم(Na^{+}) ، البوتاسيوم(K^{+}) ، الكلوريد (Cl^{-}) ، الكبريتات (SO_4^{2-}) ، TDS، وpH، حيث فحص العينات مختبرياً بكلية العلوم البيئية والأحياء البحرية بجامعة حضرموت بالطرق العلمية المعروفة. تم اعتماد المعايير الوطنية اليمنية كمعيار لتقييم العينات. أظهرت النتائج أن تراكيز Ca^{2+} :، Mg^{2+}، Cl^{-}، SO_4^{2-}، TDS وpH في جميع العينات لم تتجاوز الحدود القصوى المعتمدة في المعايير اليمنية. اما فيما يتعلق بـ Na^{+} و K^{+} فقد أظهرت النتائج أن 89% من عينات Na^{+} و 94% من عينات K^{+} فشلت في تحقيق المعايير اليمنية، وهذا قد يؤدي إلى مخاطر صحية على الانسان على المدى البعيد. خلصت هذه الدراسة إلى تقديم بعض التوصيات والمقترحات التي من شأنها تحسين وتطوير صناعة مياه الشرب المعبأة.

الكلمات المفتاحية: مياه الشرب المعبأة، خواص المياه، المواصفات اليمنية، المكلا، اليمن.

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Introduction:

Water is one of the most important substances on the Earth that life cannot go on without, and thanks God that this is an inexhaustible resource [1]. However, the rapid human increase and the prosperity of various industries pollute this resource and make it sometimes unsuitable for usage, and as a result, the pressure is increasing on the demand for safe water, including drinking water [2, 3, 4].

Scientists have long established a direct relationship between the quality of drinking water and life expectancy. Water is vital for the body, and it participates in all metabolic processes. The adult body consists of 60–70% water, which is essential for all body cells, and the average daily need for drinking water for men is from 1.4 to 2.2 liters, for women - from 1.1 to 1.8 liters [5].

The quality of drinking water in most countries of the world are regulated by national standards or international standards. Non-compliance of drinking water with sanitary norms and rules leads to numerous and varied phenomena, including diseases of the circulatory system, digestive system, endocrine glands, genitourinary system and others [6]. The issue of providing the population with drinking water of good quality is a major problem facing many countries of the world. Therefore, many governments and companies tend to intervene to contribute to the provision of safe, potable water, including bottled drinking water, and it has become a widespread trade around the world.

Despite the high cost compared to the costs of tap water services in the distribution network, especially in industrial cities, one of the quickest and easiest ways to get safe, clean water is with bottled water [3]. The demanding of bottled drinking water has drastically increased due to some reasons such as: the tourism industry development, natural disasters, health problems due to unsafe drinking water, and improved living standards of people, increasing surface and groundwater pollution, and terrorist activities [7].

The bottled drinking water industry is one of the most dynamic sectors of the food and beverage industry, and over the past decade, the global market has grown by 73%, and in 2021 global sales are estimated at about 270 billion US

dollars, compared to the sale of 350 billion liters [8]. If we look at our region, we will see that about 90% of the United Arab Emirates population consumed bottled drinking water, at a rate of about 153 liters per person in 2010, and about 95 liters per person were consumed in Saudi Arabia in 2010, whereas the contribution of bottled drinking water in Qatar was 20% of the total water consumed [9, 10, 11].

Bottled drinking water is often seen as a healthy and safe product than tap water, but there are many studies conducted around the world that showed some samples of bottled drinking water do not comply with local or international standards, and rather that some of them contain various pollutants resulting from manufacturing process. Bouhlel el al., (2023) reported that based on about 60 studies in more than 40 countries from all over the world, it became clear that there are many cases of organic, inorganic and microbiological contamination of hundreds of brands of bottled water, and that this pollution often exceeds local global standards [8]. The study conducted by Kansolea et al., (2020) in Burkina Faso indicated that the results of about 80% of the bottled water samples showed a low value of pH, it was 5 [12]. Al-Sulaili et al., (2015) also conducted the study in Kuwait, for tap and bottled water (43 samples), confirmed that the concentrations of major ions were less than the maximum values stipulated by most international agencies, while most of the elements were in accordance with the specifications of drinking water with the exception of Selenium that was above drinking water standards [13].

The study conducted by Zahid, (2002) indicated that some values of the physical and chemical specifications (pH, fluoride, manganese, sodium, sulfates and nitrates) of local and imported bottled drinking water and their differences with Saudi and international standards [14]. Razugi, et al., (2010) also indicated in their study the differences in the values of some properties such as turbidity, pH, electrical conductivity, total dissolved solids, hardness, calcium, lead, and iron in locally bottled water samples compared with imported samples that also did not comply with Iraqi standards [15]. Al-Abbas el al., (2015) indicated the results of the physical and chemical tests that were conducted for bottled water drinking samples in Iraq met the requirements of Iraqi and the

International Bottled Water Association (IBWA) standards, except for the pH, where 36% of the tested samples did not meet the standards [16]. In Yemen, Shargabi el al., (2020) conducted a study to assess the quality of bottled water marketed in the city of Ibb, 38 samples were collected and many physical, chemical and biological properties were tested. The study showed that the physical and chemical properties particularly were less than the permissible limits of the Yemeni standards [17].

In recent years, Yemen has witnessed a remarkable increase in the number of companies and factories working in the bottled drinking water industry, due to the increasing demand for its easily purchase by all classes and easily presence in all markets and groceries, as it has become invading homes, workplaces and all service facilities such as hospitals, schools, universities and other public places. Therefore, and to ensure that this industry adheres to the specified specifications and Yemeni standards, the researchers set the following goals:

- Analysis of some physical and chemical properties of a group of locally bottled drinking water brands sold in the markets in the city of Mukalla,
- Evaluate the obtained results and compare them with the Yemeni standards,
- Presenting some recommendations and proposals to the relevant authorities and institutions for the process of improvement and development of this sector.

Materials and methods:

In a random manner, 18 samples of bottles drinking water locally made in Yemen of different brands and sold in Mukalla city were purchased, three samples of each brand was analyzed, during the period from December 2020 to June 2021 (Table-1). When the samples were collected, it was taken into account that they are closed, free of defects such as deformations to avoid any contamination and are newly manufactured to avoid the possibility of changing some water properties as the expiration date approaches. The samples were kept in, a cool, well-ventilated place and away from sunlight, in laboratory at the Faculty of Environmental Sciences and Marine

Biology- Hadhramout University. All analysis were analyzed by standard analytical procedures for Water and Wastewater prescribed by APHA 1998 [18]. The physical and chemical parameters such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^{-}) were determined by Chloro meter DR900 HACH; Sulfate (SO_4^{2-})- by spectrophotometer; Sodium (Na^{+}) and Potassium- (K^{+})- by flame photometry; TDS- by conductivity meter; while pH were determined by (pH multipara meter- HANA).

Table-1 Some information about local bottled drinking water samples

No	Brand name	Company Name	Capacity, ml	Manufacture location
1	Al-Aaelah	Al-Aaelah factory for ice and ice cream	750	Seiyun
2	Gilan	Gilan Mineral Water Factory	750	Mukalla
3	Al-Jazeera	Al-Jazeera Factory	330	Seiyun
4	Al-Madinah	Hadramout Factory Complex	330	Tarim
5	Al-Sagi	Al Sagi Mineral Water Factory	750	Sana'a
6	Ruaa	Aden Company for Beverages and Industry	330	Lahj
7	Al-Lulu	Derrat Al-Safa Industrial Complex	750	Tarim
8	Maeen	Bin Jariba Mineral Water Bottling Company	750	Mukalla
9	Al-Hana	Hadramout Industrial Complex Company	750	Mukalla
10	Haban	Shabwa Mineral Water Factory	330	Shabwa
11	Taiba	Hadramout Complex - Tarbeh	330	Seiyun
12	Safa Seiyun	Safa-Saiyun Water Factory	750	Seiyun
13	Al-Masila	Al-Masila Industrial Factory	750	Tarim
14	Mawadh	Mawaddah Factory for Industry and Food	330	Tarim
15	Sugya	Sugya Factory	330	Seiyun
16	Sur Al-hayat	Al Hayat Mineral Water Factory	750	Mukalla
17	Yanabee Al-Hayat	Al-Hayah factory	750	Mukalla
18	Delta Mukalla	Delta Mukalla Healthy Water Factory	750	Mukalla

Results and Discussion:

To assess the physical and chemical properties that targeted by this study, Yemeni for bottled drinking water standards were adopted [19], as they were close to many Gulf and international standards and even more stringent regarding some determinants of bottled drinking water. All physical and chemical results are showed in the (Table-2).

Table-2: The results of the studied characteristics, their average and comparing to the
Yemeni standard

No	Brand name	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	K^{+} mg/l	Cl^{-} mg/l	$SO4^{2-}$ mg/l	TDS mg/l	pH
1	Al-Aaelah	3.5	0.6	6.5	0.11	18.2	12.5	49.0	7.2
2	Gilan	8.4	3.6	13.0	0.25	23.8	7.6	50.8	7.2
3	Al-Jazeera	9.6	2	18.0	0.05	34.0	16.5	89.4	7.2
4	Al-Madinah	15.5	5.3	12.0	0.03	23.8	6.5	108.8	7.3
5	Al-Sagi	9.0	5.8	21.3	0.23	35.7	5.4	103.1	7.4
6	Ruaa	0.5	15.4	3.0	0.33	25.5	58.3	117.1	7.3
7	Al-Lulu	6.3	3.1	13.0	0.23	25.5	7.5	107.2	7.1
8	Maeen	15.3	7.2	45.0	1.50	71.5	25.2	154.3	7.1
9	Al-Hana	10.7	8.5	26.0	1.30	40.8	24.0	114.4	7.2
10	Haban	11.3	8.3	22.0	0.70	42.5	15.5	92.1	7.2
11	Taiba	4.3	11	5.0	0.70	25.5	9.4	125.2	7.2
12	Safa Seiyun	12.4	7.3	16.0	0.23	23.8	16.0	73.8	7.1
13	Al-Masila	2.4	0.5	23.0	0.50	52.7	12.0	85.6	7.2
14	Mawadh	12.7	3.5	26.0	1.75	42.0	27.0	106.8	7.2
15	Sugya	3.5	1.4	16.0	0.30	23.8	4.6	36.5	7.1
16	Sur Al-hayat	8.5	7.5	34.7	1.50	74.9	12.6	104.0	7.2
17	Yanabee Al-Hayat	20.3	13	42.0	1.23	52.7	24.0	137.3	7.0
18	Delta Mukalla	8.7	5.7	18.0	0.15	25.5	28.5	90.4	7.2
	The average	9.1	6.1	20.0	0.6	36.8	17.4	97.0	7.2
	Yemeni standard*	65	20	90-42	1.7-4.5	200	200	650	6.5-8.0

* The maximum allowed level.

Calcium (Ca^{2+}):

Calcium concentrations in the samples ranged between 0.5 and 20.3 mg/l. The lowest was 0.5 mg/l in the Ruaa sample, while the highest value was 20.3 mg/l in the Yanabee Al-Hayat sample, while the mean value for all samples was 9.1 mg/l. All the samples results did not exceed the maximum limits allowed in the Yemeni standards (Figure-1). The results of this study are consistent with many studies conducted in the region [3, 11, 13, 14, 15, 16, and 20] in terms of calcium concentration levels and

remain within the permissible limits by the local or international agencies on which these studies were based.

Yemeni standards do not specify exact minimum values for calcium in bottled drinking water, so we see this discrepancy between the results of the samples. Studies indicate that the risk of inadequate calcium intake is a global problem [21]. Studies that carried out by Cormick el al., (2019) and Pop el al., (2023) also showed that adequate calcium intake has many health benefits, such as reducing high blood pressure disorders during pregnancy, lowering blood pressure especially among young people, preventing osteoporosis and colorectal adenomas, lowering cholesterol values, and reducing Blood pressure in the offspring of mothers who eat an adequate amount of calcium during pregnancy [22, 23], also Al-Zawali, (2019) mentioned, quoting from various sources, that the decrease in the amount of calcium entering the human body leads to the withdrawal of calcium stored in the bones, and as a result, the problem of osteoporosis appears [20]. In addition, the increased concentration of calcium gives drinking water an unpalatable taste and causes indigestion [24].

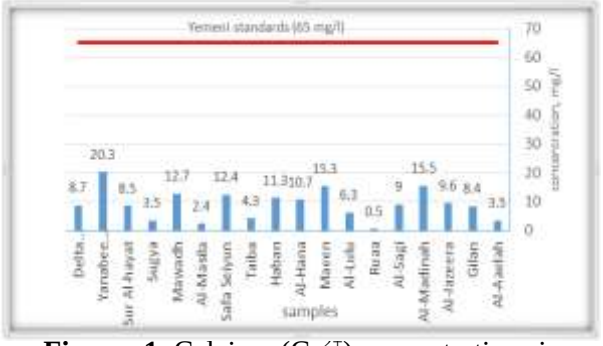


Figure- 1: Calcium (Ca^{2+}) concentrations in the samples and their comparison with Yemeni standards.

Magnesium (Mg^{2+}):

The levels of magnesium concentration in the studied samples ranged between 0.5 mg/l in the Al-Masila sample as a minimum to 15.4 mg/l in Ruaa as a maximum, whereas the average of all samples was 6.1 mg/l. These results remain within the maximum limits set by the Yemeni standards (Figure-2) and complied with many studies conducted in the region [3, 11, 13, 14, 15, 16, 17 and 20], where the magnesium concentrations did not exceed the permissible limits compared to the standards that set by those studies. WHO, (2009) indicated that inadequate intake of either nutrient can impair health, for example, low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of C- reactive protein and decreased insulin sensitivity. Low magnesium status has been implicated in

hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome [25].

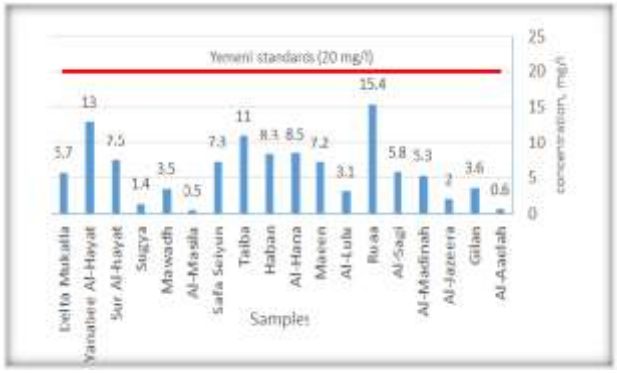


Figure- 2: Magnesium (Mg^{2+}) concentrations in the samples and their comparison with Yemeni standards

Sodium (Na^{+}):

Sodium values results of the study ranged between (3.0 and 45.0) mg/l, with average concentration values for all samples were 20 mg/l. The lowest value was 3.0 mg/l in Ruaa sample, while the highest concentration value was 45.0 mg/l in Maeen sample was. For sodium, Yemeni standards specified specific conditions which ranged between 42 and 90 mg/l. Therefore, judging by the results of all the samples (Figure-3), it can be said that only two samples, to some extent, met the Yemeni standards, namely Yanabee Al-Hayat (42 mg/l) and Maeen (45 mg/l), while 89% of the samples failed to meet the standards. The reason for this may be due to absence of the role of the authorities in the continuous monitoring of companies and factories to control the quality outputs of the products of this industry encouraged the owners of factories and companies not to check the outputs of their industries. And the confirmation of our opinion, the results of this study do not agree with many studies that were conducted in the region [3, 11, 13, 14, 16, and 20] that indicated that the levels of sodium concentrations in the studied was within the permissible limits to compare the standards on which these studies were based on. In fact, the human body needs sodium in order to maintain blood pressure, control fluid levels and for normal nerve and muscle function [11]. An excess of sodium more than 200 mg/L in drinking water may cause a salty taste or odor, as well as presenting long-term health effects [26]. Excess sodium from salt in the diet increases the risk of high blood pressure and cardiovascular disease [11].

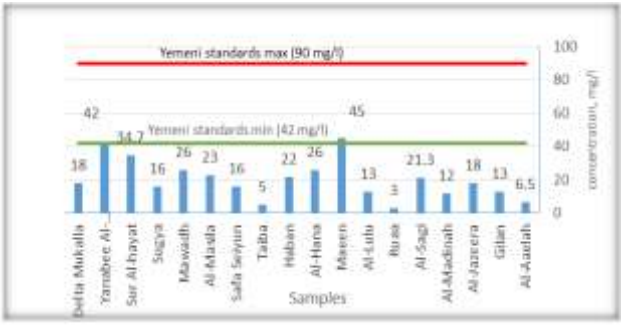


Figure- **3:** Sodium (Na^{+}) concentrations in the samples and their comparison with Yemeni standards.

Potassium- (K^+):

The results of potassium concentrations in the samples ranged between 0.03 and 1.75 mg/, where the mean concentrations of all samples was 0.6 mg/l. The lowest value was 0.03 mg/l in Al-Madinah sample, whereas the highest concentration was 1.75 in the Mawadh sample. Yemeni standards specified specific conditions for potassium, which ranged between 1.7 and 4.5 mg/l (Figure- 4). Therefore, judging by the results of all the samples, it can be said that only one samples, to some extent, met the Yemeni standards, namely Mawadh (1.75 mg/l), while 94% (17 samples) failed to meet the standards. Once again, in our opinion, the reason for the decrease this large percentage of potassium concentrations in the samples is because the absence of the role of the authorities in the continuous monitoring of companies and factories to control the quality outputs of the products of this industry encouraged the owners of factories and companies not to check the outputs of their industries. And also the results of this study do not comply with the results of several studies [3, 11, 13, 20], which conducted in the reign and found potassium levels within the permissible limits of the standards that were adopted for comparison. In fact, potassium is usually found in water in low concentrations and is not a concern to humans. However, the high solubility of potassium chloride and its use in treatment devices such as water softeners can lead to significantly increased exposure [27]. Al-Zawali (2019) mentioned (quoting from different sources) that potassium and sodium are similar in the functions that they perform, as potassium participates in balance in the body, transmission of nerve signals, and an assistant to many enzymes, and it is required for insulin secretion, creatinine phosphorylation, and carbohydrate and protein metabolism, as potassium works And sodium on the normal osmotic pressure in the cells [20].

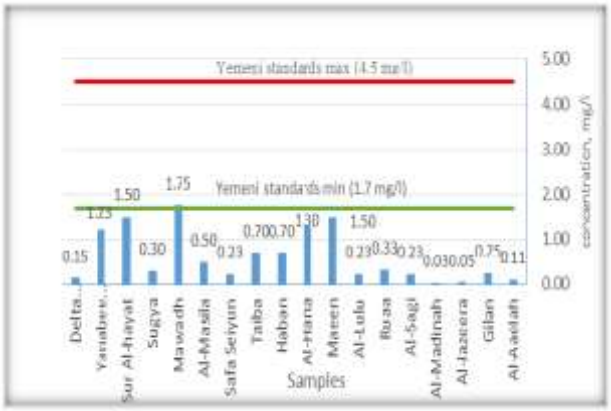


Figure- 4: Potassium (K^+) concentrations in the samples and their comparison with Yemeni standards

Chloride (Cl^-):

Through the results of the study, chlorine concentrations ranged between 18.2 and 74.9 mg/l with an average concentrations about 36.8 mg/l for all samples. It was found the lowest values of the chlorine concentration 18.2 mg/l in Al-Aaelah, whereas the highest 74.9 mg/l in Sur Al-hayat. It is clear that all samples met Yemeni standards, with chlorine concentrations not exceeding 200 mg/l (Figure-5). These results comply with the results of many studies carried out in the region [3, 11, 14, 15 and 16] which found that chlorine concentrations comply with the standards on which these studies were based on. It is true that, chloride themselves are not toxic to humans, therefore, the WHO has not prescribed a maximum permissible concentration based on their effects on health, but if it is higher than at 250 mg/l (USEPA standards), it cause a salty taste to water and can corrode pipes, pumps, and plumbing fixtures [11 and 28]. And also Wu, et al., (2021) mentioned (citing from various sources), that A severely reduced Cl intake can have negative impacts such as chronic heart failure, chronic kidney disease, liver cirrhosis, and so on [29].

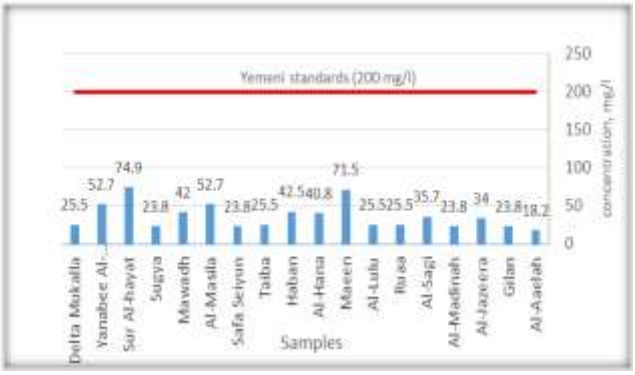


Figure- 5: Chloride (Cl^-) concentrations in the samples and their comparison with Yemeni standards

Sulfate (SO_4^{2-}):

The obtained results in this study showed that the sulfate concentration ranged between 4.6 and 58.3 mg/l, with an average about 17.4 mg/l for all samples. The lowest was 4.6 mg/l Sugya whereas the highest of sulfate value was 58.3 mg/l/ in Ruaa sample. Compared to the Yemeni standards, which indicate that the maximum allowable limits for sulfates are 200, all samples meet these standards (Figure-6). These results are also comply with many studies that were carried out in the region [3, 11, 14, 16, 17 and 20,] which met the standards on which these studies were based on. In fact, Sulfate is generally harmless, except for their effect on taste and at levels of above 1,000 mg/l, there may be laxative effects that can lead to dehydration and gastrointestinal irritation and is of special concern for infants [11]. So as

long as the sulfate does not exceed the permissible limits, it is safe.

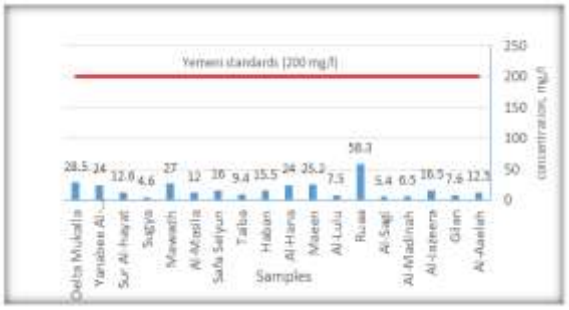


Figure- 6: Sulfate (SO_4^{2-}) concentrations in the samples and their comparison with Yemeni standards

Total dissolved solids (TDS):

The obtained results in this study showed that the concentrations of total dissolved salts (TDS) ranged between 36.5 - 154.3 mg/l. The lowest concentration value was recorded 36.5 mg/l in Sugya sample, while the highest concentration was 154.3 mg/l Maeen sample, with an average of 97.3 mg/l for all samples. Compared to the Yemeni standards that set the allowable maximum limit for TDS at 650, all samples meet these standards (Figure-7). The results of this study are consistent with many studies carried out in the Arab world [3, 14, 15, 16 and 17] to determine TDS concentrations showed their commitment to the standards on which these studies relied. And also with the most of the samples (14) in the study that conducted by Momani, (2006), in Qatar [11]. Although TDS did not exceed the permissible limits according to the Yemeni standards, the possible adverse consequences of low mineral content water consumption (low TDS) are: Direct effects on the intestinal mucous membrane, metabolism and mineral homeostasis or other body functions; Little or no intake of calcium and magnesium from low-mineral water; Low intake of other essential elements and microelements; Loss of calcium, magnesium and other essential elements in prepared food; And possible increased dietary intake of toxic metals [30]. An elevated TDS concentration is not a health hazards, because WHO considers it the aesthetic properties of water [11]

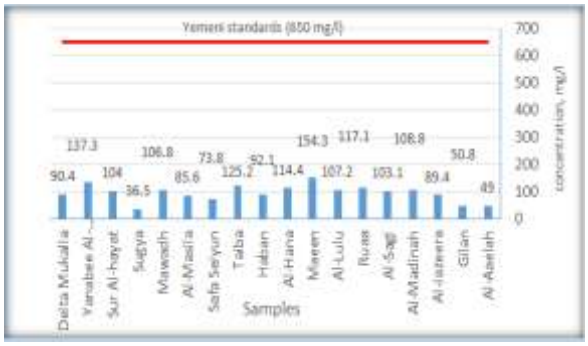


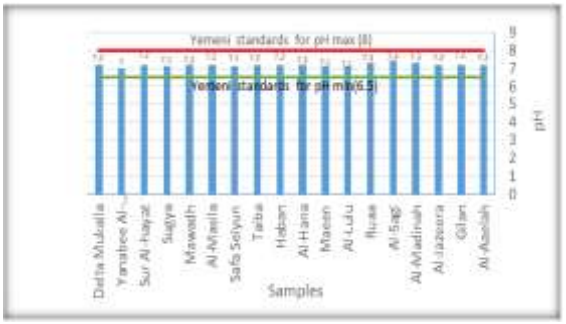
Figure- 7: TDS concentrations in the samples and their comparison with Yemeni standards

pH:

By looking to the (Figure-8), it is clear that all the pH values of all samples of this study remained within the permissible limits of the Yemeni

standards. The lowest value was 7.0 in Yanabee Al-Hayat, while the highest value was 7.4 in Al-Sagi, and with an average value about 7.2. All of samples are considered to be somewhat alkaline. The results of this study are consistent with many studies carried out in the Arab world [3, 11, 15 and 17] to determine pH value showed their commitment to the standards on which these studies relied. The results of the study also coincided with the results of the study conducted by Al-Zahid (2015), with a large percentage that formed about 97% of the samples [14]. However, the results of this study did not agree with the results of the study of Al-Abbas, and Al-Musawi (2015), as they found about 36% of the samples exceeded the permissible limits in their study [16]. In fact, pH has no direct effects on consumers, but it should be well monitored to ensure the safety of water during all processes of treatment [3]. While pH at values less than 6.5, water is corrosive and dissolves plumbing components especially when pipes are made of copper, zinc or lead, high pH values more than 8.5 of drinking water can promote hardness scale precipitation and make chlorine disinfectants more effective [11]

Figure- 8: pH value in the samples and their comparison with Yemeni standards



Conclusions:

1. 18 random samples of local bottled drinking water from different companies were randomly selected from markets in the Mukalla city during the period from December 2020 to June 2021 for the purpose of evaluating some physical and chemical properties: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, TDS and pH.
2. All samples were analyzed in the laboratories of the Faculty of Environmental Sciences and Marine Biology- Hadhramout University. The results of all sample analyzes were compared with Yemeni standards, as they meet many agency, international and regional standards.
3. Although the results of calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations of all samples varied in wide range, they did not exceed the Yemeni standards. The reason

may be that the failure to specify the minimum level for these concentrations in the Yemeni standards made this difference possible.

4. The results of sodium (Na^+) and potassium (K^+) showed that it did not meet the specified Yemeni standards for a large percentage of the samples, 89% for sodium and 94% for potassium. The reason for that might be due to the absence of the role of the concerned authorities to continuous control on companies and factories to quality control of the outputs of the products of this industry. This encouraged the owners of factories and companies not to monitoring their outputs.
5. The results of the chlorine (Cl^-), sulfate (SO_4^{2-}) and TDS of all samples comply with Yemeni standards and did not exceed them. And also the variation in the results of the samples between them may be due to the failure to specify the minimum level for these concentrations in the Yemeni standards
6. As for the pH, the Yemeni standards set minimum and maximum limits for it. Where all the results of the samples came within these limits, and showed their tendencies towards alkalinity to some extent.

Recommendations:

1. The concerned authorities must play their role in continuously monitoring the quality of bottled drinking water for operating companies and factories and oblige them to follow national standards.
2. Oblige companies and factories operating in the bottled drinking water industry to establish quality departments in their own, or to benefit from laboratories or laboratory centers, especially those of universities and institutes, to monitor the quality of bottled drinking water in partnership with the concerned authorities.
3. Establish a database for the bottled drinking water industry by the concerned authorities including the results of periodic tests for factories, companies and agencies that carry out these tests to verify the credibility of quality standards and their commitment to national standards.
4. Apply legal deterrent measures to violating companies and factories,

and put them on the blacklist for not applying quality standards

5. Hold guidance and awareness courses for employers and worker holders in the bottled drinking water industry.
6. Activate the role of organizing campaigns and sudden field trips to companies and factories which working in this field.
7. Determine of minimum limits for some physical and chemical properties such as calcium, magnesium, chlorine, sulfate and TDS by the Yemeni Standards and Metrology Authority to ensure better quality of bottled drinking water.
8. Compel companies and factories to write all real data on the information tape (including the water source, treatment quality, etc.) and update it continuously.

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