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Assessment of Reverse Osmosis Water and Some Types of Packaged Bottled Water in Basra City, Southern Iraq

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Abstract - Global sales of mineral water have increased considerably to reach a value of more than 35 billion US dollars, mainly due to public perceptions of its purity and safety, as well as public concerns about the quality of tap water.
A total of 24 samples (12 reverse osmosis (RO) water samples taken from three regions and 12 samples of three brands of bottled water) were collected randomly. The samples were analyzed using the membrane filtration technique for their bacteriological quality (total and fecal coliforms per 100 mL). In addition, physiochemical analyses were undertaken to determine the dissolved oxygen, electrical conductivity, temperature, pH, total dissolved salts, turbidity, nitrate, calcium, magnesium, and chloride ions.
Out of 12 RO water samples tested only 9 (75%) gave positive results for total coliforms, while 6 (50%) gave positive results for fecal coliforms. In contrast, 3 (25%) samples of bottled water gave positive test for total coliforms and 6 (50%) were positive for fecal coliforms.
Both the RO and bottled water were contaminated with total and fecal coliforms, especially in hot months, and they reached unacceptable limits. Meanwhile, the physiochemical parameters were within acceptable limits, except in one sample, where the values of ions of calcium, magnesium, and chloride had been risen. According to the results obtained in this study, there should be a review of the water treatment process by water laboratories, especially in the summer, and there should be follow-ups by the inspection teams from the health and environment departments.

تقييم مياه التناضح العكسي وبعض انواع المياه المعبأة في محافظة البصرة جنوب العراق

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المستخلص - ازدادت المبيعات العالمية للمياه المعدنية بشكل كبير لتصل إلى أكثر من 35 مليار دولار أمريكي، ويرجع ذلك أساسا إلى التصورات العامة لنقاوتها وسلامتها، فضلا عن المخاوف العامة بشأن جودة مياه الصنبور تم جمع 24 عينة (12 عينة مياه بالتناضح العكسي مأخوذة من ثلاث مناطق و 12 عينة من ثلاث علامات تجارية من المياه المعبأة في قناني بلاستيكية) بشكل عشوائي. تم تحليل العينات باستخدام تقنية الترشيح الغشائي لتحديد جودتها من الناحية البكتريولوجية (القولونيات الكلية والبرازية لكل 100مل). بالإضافة إلى ذلك، تم إجراء تحليلات فيزيوكيميائية لتحديد الأكسجين المذاب

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والتوصيل الكهربائي ودرجة الحرارة ودرجة الحموضة والأملاح الذائبة الكلية والعكارة والنترات والكالسيوم والمغنيسيوم وأيونات الكلوريد. تم اختبار تسعة من عينات المياه الاثني عشر لمياه التناضح العكسي وكانت موجبة لمجموع القولونيات 75% ، في حين كانت ستة من العينات لمفحوصة موجبة للقولونيات البرازية 50%. في المقابل، ثبتت إيجابية ثلاث عينات من المياه المعبأة في قناني لمجموع القولونيات 25% ، وستة إيجابية للقولونيات البرازية 50 %.كانت كل من مياه التناضح العكسي والمياه المعبأة ملوثة بالقولون الكلي والبرازي ، خاصة في الأشهر الحارة ، ووصلت إلى حدود غير مقبولة. وفي الوقت نفسه، كانت الخصائص الفيزيائية الكيميائية ضمن الحدود المقبولة ، باستثناء عينة واحدة ، حيث ارتفعت قيم أيونات الكالسيوم والمغنيسيوم والكلوريد. وفقا للنتائج التي تم الحصول عليها في هذه الدراسة، يجب أن يكون هناك مراجعة لعملية معالجة المياه من قبل مختبرات المياه، خاصة في فصل الصيف ، ويجب أن تكون هناك متابعة من قبل فرق التفتيش من أقسام الصحة والبيئة.

الكلمات المفتاحية: الجودة البكتيرية ، القولون البرازية، القولون الكلية ، المحددات الفيزيوكيميائية.

Introduction

Water is considered as a significant basic resource for all mankind, as well as in agriculture and industry. Social and economic progress depends on this exceptional and sustainable resource (Taiwo *et al*., 2012; Curutiu *et al*., 2019). The availability, accessibility, and quality of drinking water is a fundamental human right, and the UN General Assembly has listed the universal obtainability of drinking water and sanitation as one of the sustainable development objectives to be achieved by 2030 (United Nations Environment Programme, 2010; United Nations, 2018).

The true indicators of water quality are the chemical, physical, and biological properties of the water, which determine its uses, including human health and the water ecosystem (Hubert *et al*., 2015; Curutiu *et al.*, 2019). These properties can affect water quality when they are influenced by water-soluble components, as well as natural processes and human activities (DWA, 2010).

From the moment of its application, water security can ensure sustainable access to water in sufficient quantities and of acceptable quality to ensure human livelihoods, well-being, and social and economic growth. Water security can also guarantee protection from pollution and maintain ecosystems in a climate of peace and political balance (Lu *et al*., 2015).

The World Health Organization (2011) announced that approximately 1.1 billion people worldwide take in unprocessed water and that most cases of diarrhea (88%) are due to untreated water and unhealthy practices. Furthermore, the water supply sector is facing enormous challenges due to climate change, global warming, and urbanization. Insufficient water volumes and poor water quality have serious impacts on sustainable development, especially in developing countries.

Water quality is affected, especially with regard to microbiological contamination, during collection, transportation, and domestic storage. Possible sources of contamination of drinking water are animal waste, economic activities (agricultural, industrial, and commercial), and waste from residential areas. Water sources are particularly susceptible to such contamination (Oljira, 2015).

Therefore, access to a safe source alone does not guarantee the quality of water consumed, and a good water source alone does not automatically offer full health benefits if water storage and sanitation are not improved (Clasen *et al*., 2007). In the developing countries, it has been observed that drinking water is frequently re-contaminated after collection and during home storage (Too *et al*., 2016).

The current study was conducted in Basra City, southern Iraq, to evaluate the water quality of RO tanks and bottled water and determines which type is the better choice for drinking and household uses.

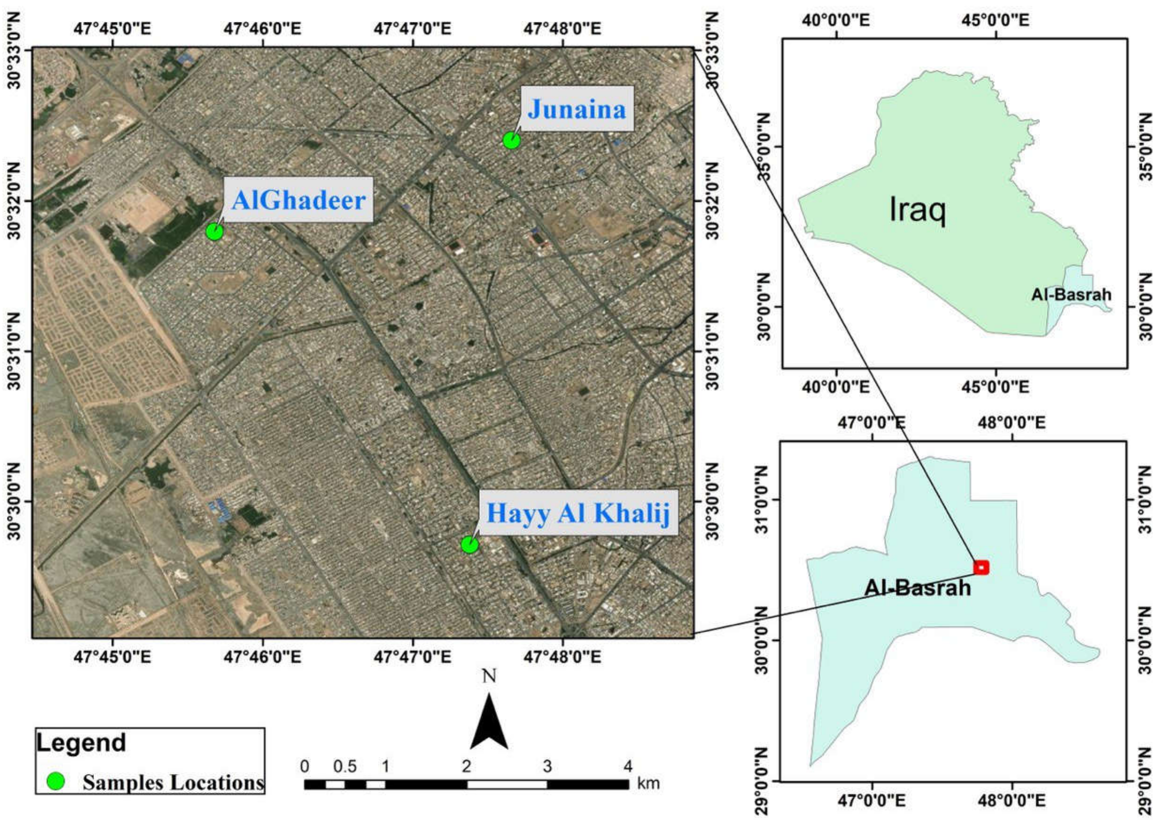
Materials and methods

Sampling

Reverse osmosis water was taken from three districts in Basra City, including Al-Ghadeer district, Al-Khaleej district and Al-Juneina district, from tanks that distribute water to residential neighborhoods (Fig. 1).

Samples were collected in 500 mL sterile glass bottles and kept in an ice box, according to SMWW section 9060 A (2015).

In addition, three brands of bottled water (Alrahma, Aquafina and Durrat Al Khaleej) were taken randomly from a local market between April and August 2023.



(Figure 1) Stations for sampling from Al-Juneina, Al-Ghadeer, and Al-Khaleej districts in Basra city southern Iraq.

Bacteriological Analysis

According to Section 9222B for total coliforms and Section 9222D for fecal coliforms of SMWW (2015), four replicates of 25 mL of each sample were filtered through a 0.45 µm membrane filter (Merck, Germany).

For the total coliforms, membrane filters were placed on the surface of M-endo agar LES and incubated at 35 ± 0.5 °C for 24 ±2 h. occurring of pink to dark red colonies with a metallic surface sheen referred to a typical coliform. The sheen area may vary in size from that of a pinhead to complete colony coverage.

For the thermtolerant coliforms, bacteria were placed on a filter membrane on mFC agar containing aniline blue as the indicator without 1% rosolic acid. Incubation in a water bath took place at 44.5 ± 0.2 °C for 22-24 h. Colonies colored various shades of blue would be positive for fecal coliforms.

Physicochemical analysis

Magnesium and Calcium were titrated with 0.01N EDTA- Na_2. Cl was determined volumetrically by titration with 0.01 N $AgNO_3$. The Cd reduction method was used to determine NO_3, and pH was measured using a pH meter (SD 305, Lovibond, Germany). EC and TDS were measured using a conductivity meter (SD 325, Lovibond, Germany). Dissolved oxygen was measured using an Oxi meter (SD400 Oxi- L, Lovibond, Germany). All the Physical and Chemical properties analysis were done according to APHA (2005).

Results and Discussion

Water is a basic need for every form of life, but man continues to pollute the remaining reserves, which increases the risk that disease may occur (Al-Sulami *et al*., 2013).

In the current study, the water quality index (WQI) was determined by evaluating 10 physio-chemical parameters according to a weighted arithmetic index from six water sources in Basra City in order to assess the suitability of these sources for drinking purposes. The pH values ranged between 6.84 and 8.44, with the average being 7.69 (Fig 2). These results are adequate with regard to the WHO and Iraqi standard limits (6.5– 8.5) (Table 1).

The EC values ranged between 5.0 and 278 μScm^{-1}, and the average was 95.3 μScm^{-1}. Thus, the EC of most of the samples was within the acceptable limits, based on the recommended WHO (2011) standard for EC, which is 250 μScm^{-1}, only sample 1 exceeded the standard value (Fig. 3).The TDS values ranged between 3.13 and 391 mgL^{-1}, and the average was 101.65 mgL^{-1}. These results exceeded the standard value (Fig. 4). The EC values were correlated with the TDS values (Barbooti *et al*., 2010). The DO values ranged from 8.06 to 11.0 mgL^{-1}, and the average was 9.43 mgL^{-1}, so these results exceeded the WHO and Iraqi standards (Fig. 5).

Figures 6, 7, 8, and 9 show the frequency concentration values of No3, Ca, Mg, and Cl respectively. The NO_3 concentration values ranged from 0.0 to 1.2 mgL^{-1}, and the average was 0.48 mgL^{-1}. The results are within the acceptable limits of the WHO and Iraqi standards.

The Calcium concentration values ranged from 0.4 to 12 mgL^{-1}, and the average was 7.74 mgL^{-1}. The results are within the acceptable limits of the WHO and Iraqi standards.

The range of magnesium concentration values was 0.48 to 19.47mgL^{-1}, and the average was 4.29 mgL^{-1}. The results are within the acceptable limits of the WHO and Iraqi standards.

The range of chloride concentration values was 1.98 to 546.7 mgL^{-1}, and the average was 60.83 mgL^{-1}. Most results are adequate with the WHO and Iraqi standards, except a few results which exceeded them.

The bacterial analysis results (Table 2) showed variations in the number of total and fecal coliforms among the tested samples during the period of study, especially in the hot months (May, June, and July). TC was detected in the three samples of RO (100%), and two of the three samples of bottled mineral water (66.6%), while all the samples were positive for FC. These results are Correspond to Al-Sulami *et al.* (2014) and Al-Sulami *et al*. (2012), who found that RO water and drinking water were contaminated with *Aeromonas hydrophila* and *Mycobacterium avium complex*, respectively. The present results also match with the findings of Hasan *et al.* (2014), who studied the fecal and total coliforms in bottled water and found variations in the numbers of these bacteria. In recent studies, Agbendeh and Ogbonna (2022) and Keleb *et al.*

(2022) found that most packaged water bottles were contaminated with pathogenic bacteria, and they concluded that this industry needed urgent monitoring and strictly enforced hygienic measures.

According to the WHO guidelines and Iraqi standards, the microbial quality of bottled drinking water and RO water make both types unsuitable for drinking, which especially applied to the tested samples.

(Table 1) Values of different parameters in the period of study according to Iraqi standard and world health organization standard.

Parameter	Sample	April	May	June	July	August	IS	WHO
pH	1	7.68	7.08	7.66	8.12	8.12	6.5-8.5	6.5-8.5
	2	7.36	7.4	7.42	8.44	8.44		
	3	7.91	7.1	7.48	8.25	8.25		
	4	6.84	6.91	7.11	8.2	8.2		
	5	7.43	7.51	7.6	8.42	8.42		
	6	7.02	7.0	7.0	8.31	8.31		
Total	Mean	7.37	7.17	7.38	8.29	8.29		
	Std. Deviation	0.399	0.236	0.267	0.125	0.125		
DO mgL^{-1}	1	8.24	8.86	9.5	8.6	8.80	6.5-8	6.5-8
	2	8.58	8.58	8.41	8.4	8.49		
	3	8.51	8.06	8.69	8.5	8.44		
	4	10.18	11.0	9.32	9.6	10.03		
	5	8.85	8.85	10.21	9.4	9.33		
	6	8.75	9.0	10.65	9.5	9.48		
Total	Mean	8.85	9.06	9.46	9.00	9.10		
	Std. Deviation	0.684	1.008	0.860	0.555	0.626		
EC μscm^{-1}	1	266.0	90.8	110.0	278.	171.0	-------	250
	2	60.8	92.6	9.5	21.3	10.0		
	3	103.7	85.1	103.0	94.0	76.6		
	4	206.2	203	191.0	196.	191.0		
	5	66.1	64.3	14.0	56.5	46.3		
	6	6.62	11.3	5.0	9.7	20.4		
Total	Mean	118.24	91.18	72.08	109.25	85.88		
	Std. Deviation	98.243	62.684	75.266	106.454	77.452		
TDS mgL^{-1}	1	391.0	40.36	55.47	177.92	109.44	100.0	100.0
	2	29.3	66.71	69.8	13.63	6.4		
	3	50.3	49.3	44.34	60.16	19.88		
	4	100.9	101.0	99.78	125.44	122.24		
	5	32.0	40.0	65.0	36.16	29.632		
	6	3.13	13.5	15.2	6.2	9.94		
Total	Mean	101.11	51.81	58.27	69.92	49.59		
	Std. Deviation	145.706	29.618	28.136	68.133	52.112		
NO_3 mgL^{-1}	1	0.2	0.1	0.3	0.1	0.2	20.0	10.0
	2	0.5	0.7	0.3	0.1	0.4		
	3	0	0.2	0.5	0.4	0.3		
	4	0.3	0.5	1.2	0.6	0.7		
	5	1.0	1.2	0.9	0.4	0.9		

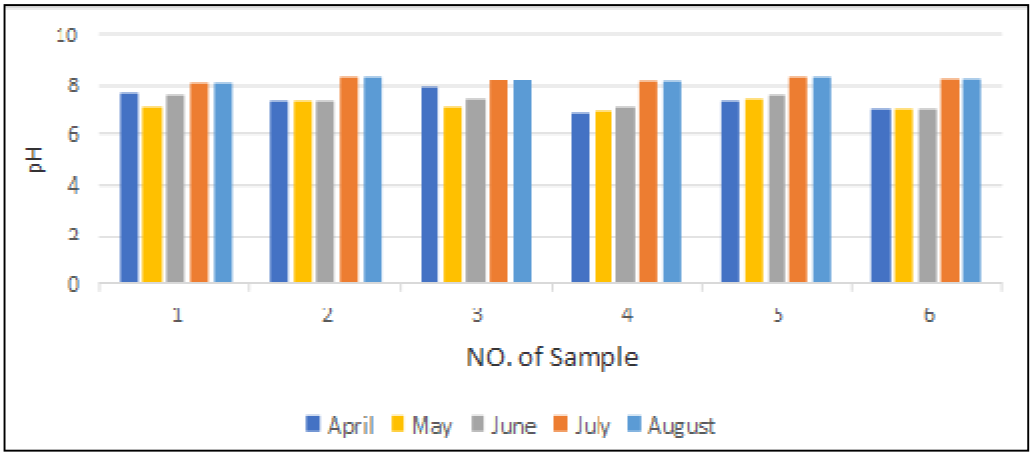
Parameter	Sample	April	May	June	July	August	IS	WHO
	6	---	---	---	---	---		
Total	Mean	0.4	0.54	0.64	0.32	0.5		
	Std. Deviation	0.381	0.439	0.397	0.217	0.292		
Ca mgL^{-1}	1	---	12.0	1.2	12.0	12.0	200.0	75.0
	2	2.8	1.6	0.4	1.6	0.8		
	3	4.0	4.8	0.8	4.8	3.2		
	4	2.4	12.0	1.2	12	1.6		
	5	1.6	0.8	---	4.0	1.6		
	6	2.1	4.0	2.0	0.8	0.8		
Total	Mean	2.58	5.87	1.12	5.87	3.33		
	Std. Deviation	0.907	4.975	0.593	4.975	4.335		
Mg mgL^{-1}	1	---	19.44	0.97	19.47	6.07	50.0	30.0
	2	0.48	2.43	0.48	2.43	0.72		
	3	1.94	1.45	0.48	1.45	0.97		
	4	1.45	18.95	0.48	18.95	7.95		
	5	0.48	0.97	3.58	2.43	10.43		
	6	3.51	2.43	0.72	0.97	9.94		
Total	Mean	1.57	7.61	1.12	7.62	6.01		
	Std. Deviation	1.254	8.992	1.222	8.999	4.293		
CL mgL^{-1}	1	546.7	61.62	304.16	61.62	243.53	200.0	200.0-300.0
	2	4.97	5.98	5.475	5.96	5.60		
	3	19.88	20.87	20.375	20.87	20.50		
	4	117.76	41.74	79.75	41.78	70.26		
	5	36.67	1.98	19.326	13.91	17.97		
	6	3.71	13.91	8.81	1.98	7.10		
Total	Mean	121.62	24.35	72.98	24.35	60.83		
	Std. Deviation	212.502	23.024	116.457	23.033	92.595		

Al-Jamaayat (1), Al-Ghadeer (2), Al-Junaina (3), Aquafina (4), Durrat Al-Khaleej (5), Al-Rahma (6)

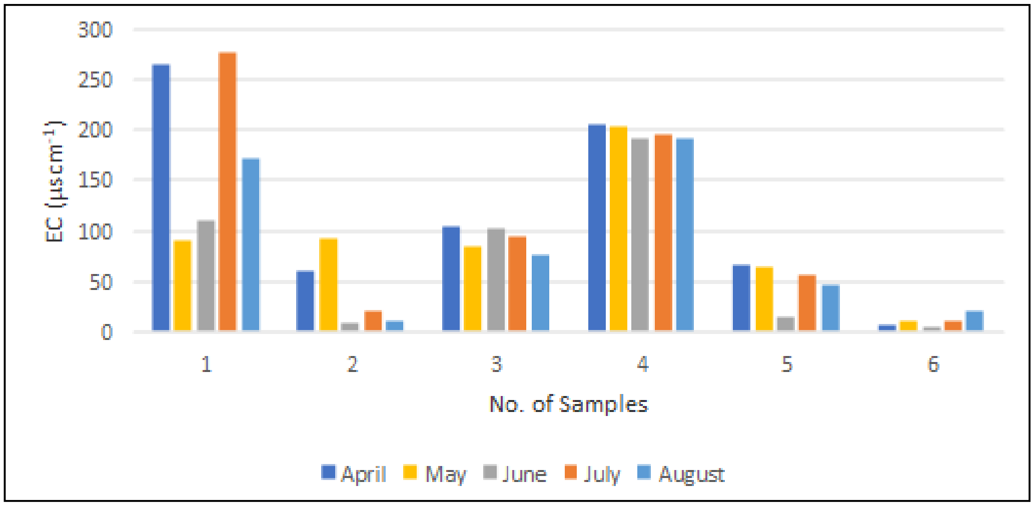
(Table 2) Numbers of total and fecal coliform in the period of study according to Iraqi standard and world health organization standard.

Bacteria	Sample	April	May	June	July	August	IS	WHO
TC ($CFUmL^{-1}$)	1	Nil	$3.6 X10^{2}$	$4.5X10^{4}$	$5 X 10^{4}$	Nil	NIL	NIL
	2	Nil	$3.0X 10^{3}$	$1.0X 10^{1}$	$3.0X 10^{4}$	Nil		
	3	Nil	$0.9 X10^{1}$	$6.0 X10^{4}$	$8.0X10^{4}$	Nil		
	4	Nil	Nil	Nil	$4.0X10^{4}$	Nil		
	5	Nil	Nil	Nil	Nil	Nil		
	6	Nil	Nil	$2.8X 10^{2}$	$6.0X10^{4}$	Nil		
FC ($CFUmL^{-1}$)	1	Nil	Nil	$8.0X 10^{3}$	$4.0X10^{4}$	Nil	NIL	NIL
	2	Nil	Nil	$6.0X 10^{3}$	$3.8X10^{2}$	Nil		
	3	Nil	Nil	$2.0X 10^{3}$	$2.8X10^{2}$	Nil		
	4	Nil	Nil	$4.2X 10^{1}$	$3.0X10^{3}$	Nil		
	5	Nil	Nil	$0.4 X10^{1}$	$3.0X10^{2}$	Nil		
	6	Nil	Nil	$3.6 X10^{1}$	$3.0X10^{2}$	Nil		

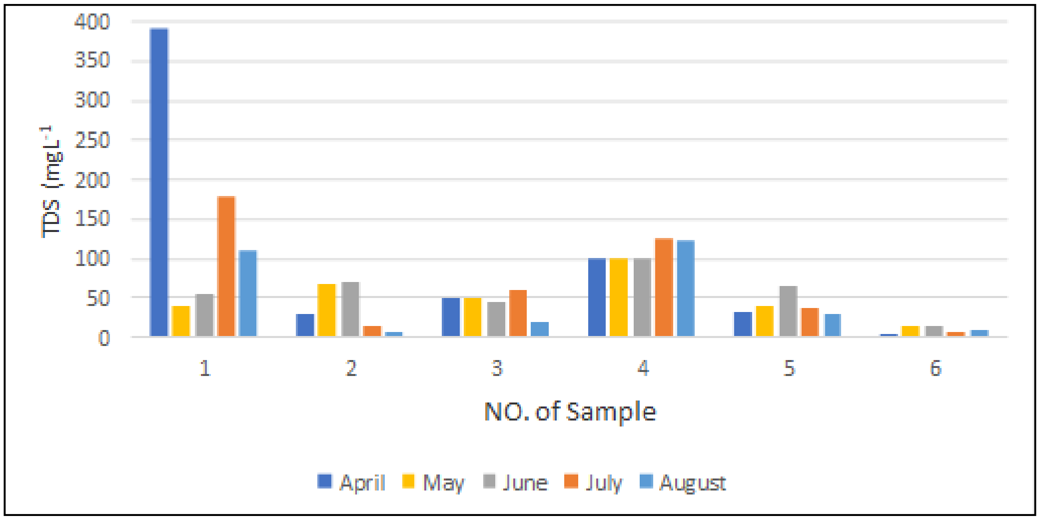
Al-Jamaayat (1), Al-Ghadeer (2), Al-Junaina (3), Aquafina (4), Durrat Al-Khaleej (5), Al-Rahma (6), $CFUmL^{-1}$: Colony Forming Unit/ milliliter.



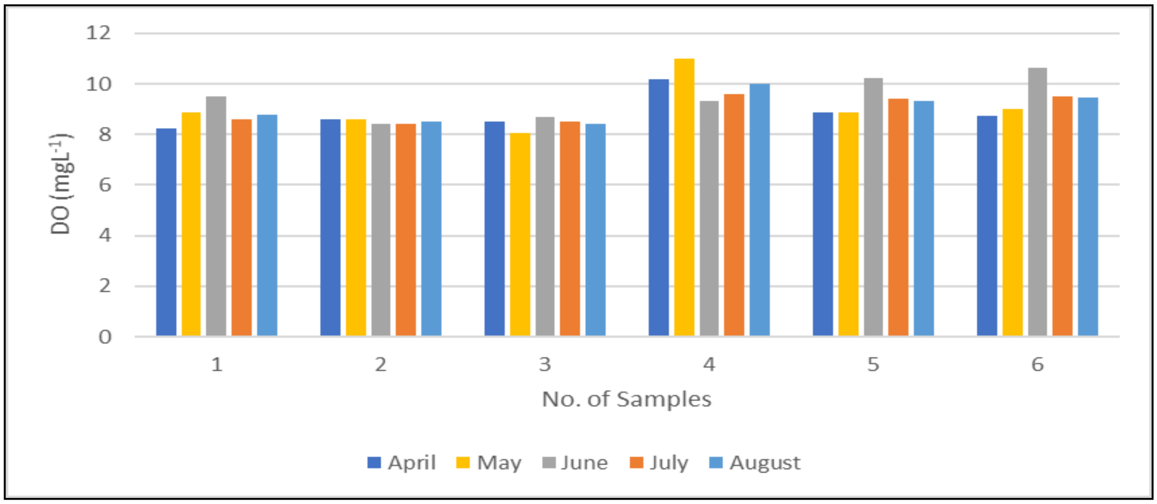
(Figure 2) Values of pH for different samples and period.



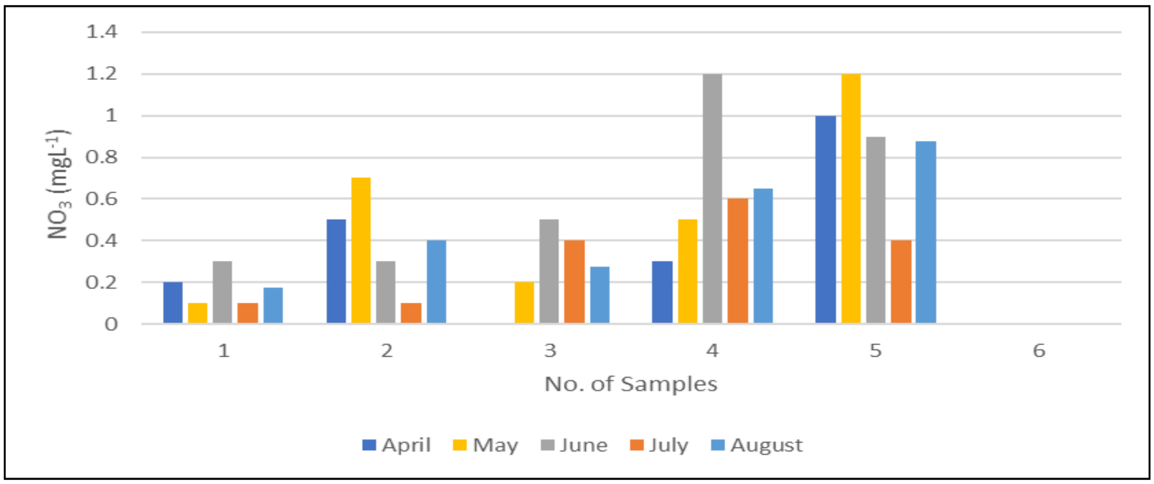
(Figure 3) Values of EC for different samples and period.



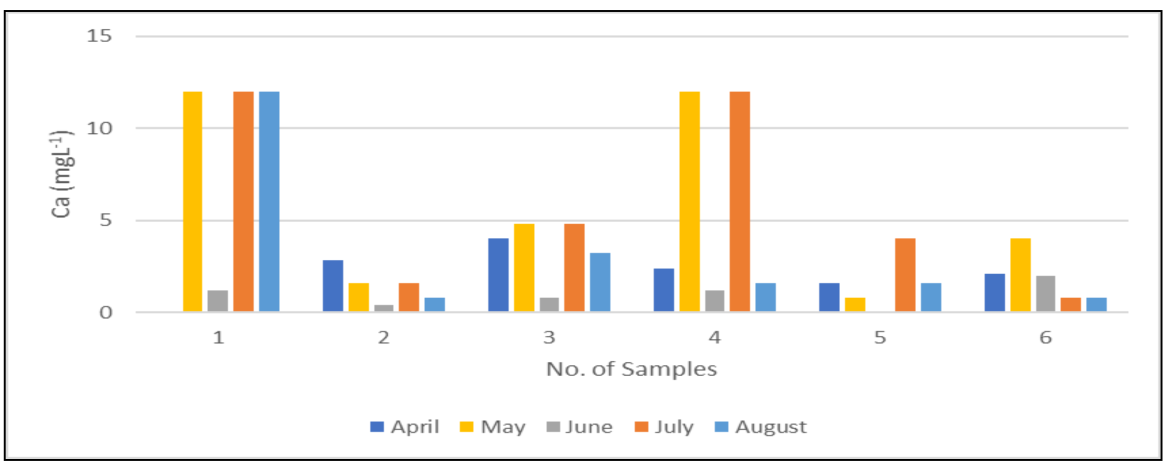
(Figure 4) Values of TDS for different samples and period.



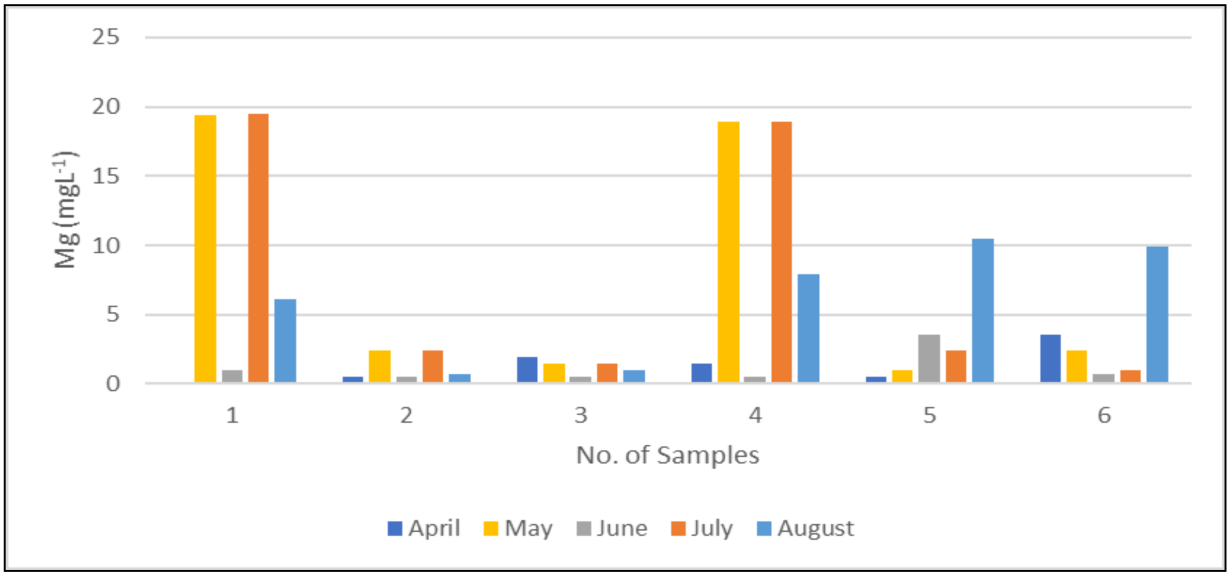
(Figure 5) Values of DO for different samples and period.



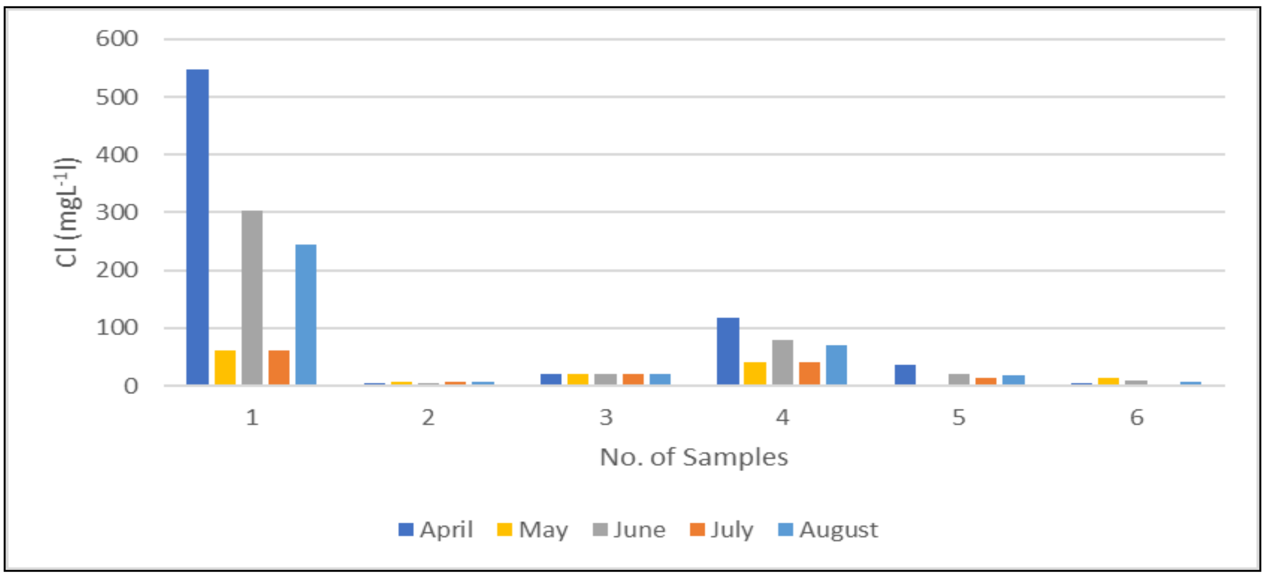
(Figure 6) Values of NO_3 for different samples and period.



(Figure 7) Values of Ca for different samples and period.



(Figure 8) Values of Mg for different samples and period.



(Figure 9) Values of Cl for different samples and period.

Conclusions

Total and fecal coliforms may contaminate all water sources, so it is strongly recommended to treat water before using it. The study showed that unimproved sources were considered unsuitable for human consumption. Water from unimproved sources is generally unsafe to consume, even if it is used as an alternative water supply. People should be concerned about drinking water sources and health risks that go beyond acceptable safety limits.

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