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Characteristics of Drinking Water Quality from Decentralized Units in Traghen : A Comparative Study with International and Local Standards

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خصائص جودة مياه الشرب من الوحدات غير المركزية في تراغن: دراسة مقارنة بالمعايير العالمية والمحلية

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Abstract:
This study aims to evaluate the performance of decentralized water treatment units in Traghen, Libya, by monitoring the quality of the produced water and comparing it with both national and international standards. A descriptive analytical approach was adopted, and six water samples were collected from three primary locations: the City Entrance, Student Housing, and the Grand Mosque (designated as C, B, and A, respectively). Three samples were taken from the water source before desalination, and three were collected after treatment from each site.
Laboratory analyses included the measurement of key physicochemical parameters, such as pH, electrical conductivity (EC), and total dissolved solids (TDS). The concentrations of major ions, including sodium (Na+), potassium (K+), calcium (Ca++), magnesium (Mg++), chloride (Cl-), sulfate (SO_4^{2-}), and bicarbonate (HCO_3-), were also determined. Additionally, nitrate (NO_3-) levels were measured. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), employing both an independent samples T-test and one-way analysis of variance (ANOVA) at a significance level of α=0.05.
The results indicate that most of the physicochemical indicators for the treated water comply with national and international drinking water standards. The pH values ranged from 6.7 to 7.1, and all major ion concentrations were within the permissible limits. Nitrate concentrations across all samples were either very low or below the detection limit. However, a slight increase in the electrical conductivity and total dissolved solids was observed in some units after treatment, particularly at stations A and C. Furthermore, elevated concentrations of certain ions, such as sodium and chloride, were recorded at station C post-treatment. This suggests a variation in the efficiency of the desalination units and an incomplete removal of salts, a potential issue that could be attributed to manufacturing defects or a lack of proper maintenance and filter replacement.

Keywords: Drinking water, Desalination, Decentralized units, Physicochemical properties, Traghen.

الملخص
تهدف هذه الدراسة إلى تقييم فعالية وحدات معالجة المياه اللامركزية في مدينة تراغن، ليبيا، من خلال مراقبة جودة المياه المنتجة ومقارنتها بالمعايير المحلية والدولية. اعتمدت الدراسة المنهج الوصفي التحليلي، حيث تم جمع ست عينات من ثلاثة مواقع رئيسية (مدخل المدينة، السكن الطلابي، المسجد الكبير) (C، B، A) على التوالي، بواقع ثلاث عينات من المصدر المائي قبل التحلية وثلاث بعد التحلية من كل موقع. شملت التحاليل المخبرية قياس الرقم الهيدروجيني (pH)، التوصيل الكهربائي (EC)، الأملاح الذائبة الكلية (TDS)، بالإضافة إلى أيونات رئيسية مثل الصوديوم (Na+), البوتاسيوم (K+), الكالسيوم (Ca++), المغنيسيوم (Mg++), الكلوريد (Cl-), الكبريتات (SO4--), والبيكربونات (HCO3--). كما تم قياس

النترات (NO3-). تم تحليل البيانات باستخدام الحزمة الإحصائية للعلوم الاجتماعية (SPSS) مع اختبار T-test وتحليل التباين الأحادي (ANOVA) عند مستوى دلالة α=0.05.
أظهرت النتائج أن معظم المؤشرات الفيزيوكيميائية للمياه المعالجة تقع ضمن المعايير القياسية المحلية والدولية لمياه الشرب، حيث تراوحت قيم الرقم الهيدروجيني بين 6.7 و 7.1، وجميع تراكيز الأيونات الرئيسية كانت ضمن الحدود المسموح، وكانت تراكيز النترات في جميع العينات منخفضة جدًا أو معدومة (أقل من حساسية الجهاز). ومع ذلك، لوحظ ارتفاع قيم التوصيل الكهربائي والأملاح الذائبة الكلية في بعض الوحدات بعد المعالجة مقارنة بما قبلها، خاصة في المحطتين "A" و "C". كما سجلت زيادات في تراكيز بعض الأيونات (مثل الصوديوم والكلوريد) في المحطة "C" بعد المعالجة، مما يشير إلى تباين في كفاءة وحدات التحلية وعدم فعاليتها الكاملة في إزالة الأملاح. يُعزى هذا القصور المحتمل إلى رداءة التصنيع أو نقص الصيانة الدورية لهذه الوحدات.

الكلمات المفتاحية: مياه الشرب، التحلية ، وحدات غير مركزية ، خصائص فيزيوكيميائية ، تراغن.

Introduction

Water is one of the most valuable resources on our planet, and with the growing global population, the demand for fresh water is rising rapidly. Desalination offers a compelling solution to water scarcity issues, especially in arid and semi-arid regions. By removing salt and other impurities from seawater or brackish water, desalination processes can provide a reliable supply of drinking water. However, evaluating the effectiveness of these processes is critical to ensure the provision of water that meets quality standards. This study addresses the effectiveness of water desalination processes through water quality monitoring.

Desalination is a complex process that involves the removal of salts and other impurities from saltwater to produce fresh water suitable for human consumption, agriculture, and industrial use. There are two main types of desalination technologies: thermal processes and membrane processes. Each of these technologies has its unique methods and advantages [1].

Thermal desalination processes include multi-stage flash distillation, multi-effect distillation, and vapor compression. Multi-stage flash distillation works by heating brackish water and converting it into vapor in multiple stages, then condensing it into fresh water. On the other hand, multi-effect distillation uses multiple stages of evaporation and condensation, while vapor compression relies on water evaporation and vapor pressure to produce desalinated water. These processes are energy-intensive but are effective in areas where energy costs are low or where waste heat is available.

Membrane processes primarily consist of reverse osmosis and electrodialysis. Reverse osmosis involves forcing seawater or brackish water through semi-permeable membranes that block salts and other impurities, allowing only fresh water to pass through. Reverse osmosis is highly efficient but requires significant energy input and membrane maintenance. Electrodialysis uses an electric voltage to drive ions through selective membranes, separating salts from the water. While the energy requirements for electrodialysis are generally lower than for thermal processes, it is often less effective for water with high salinity [2].

Salinity, or the concentration of salt in water, is the most obvious measure of desalination effectiveness. A high-quality desalination process will produce water with salinity levels that comply with guidelines set by organizations such as the World Health Organization. Reducing salinity to acceptable levels indicates that the process effectively removes the bulk of dissolved salts.

The pH level of the water must also conform to human consumption standards, typically ranging between 6.5 and 8.5. Water that is too acidic or alkaline can affect taste, be harmful if consumed for prolonged periods, and can cause plumbing corrosion. Specific ions such as calcium, magnesium, sulfates, chlorides, and heavy metals are also essential for monitoring. Some of these minerals, such as calcium and magnesium, are essential but are harmful in high concentrations [3].

Research Problem

Despite the significant progress made in desalination processes, they face several challenges and limitations that may affect their effectiveness and widespread adoption. These challenges need careful management to ensure the production of high-quality water and the sustainability of desalination operations. With the widespread use of decentralized desalination units and reliance on them as a primary source of drinking water in many areas, especially given the great variety of these units, there is a possibility that the resulting desalinated water may not comply with international and local standards.

Research Importance

Water quality monitoring is a fundamental component of evaluating desalination processes. Effective monitoring ensures that the treated water meets safety and quality standards, which protects public health and the environment. It includes the analysis of several parameters, including salinity, pH, and the concentrations of specific ions and contaminants. Through comprehensive water quality monitoring, the effectiveness of desalination processes can be ensured, and public health and environmental sustainability can be protected.

Research Objectives
Determine the physicochemical properties of drinking water produced from decentralized desalination units in the city of Traghen.
Compare the results with local drinking water standards and international standards issued by the World Health Organization.
Measure the effectiveness of desalination units in removing salts.

Research Questions
Are the physicochemical properties of the treated water from the desalination stations in the city of Traghen within the permissible range according to local and international standards?
Are the water treatment units widespread in the city operating efficiently?

Research Methodology
The study follows a descriptive analytical approach to ensure that the research questions are answered.

Material and methods
Water samples were collected from the three main locations equipped with desalination units:

Table 1 Treatment Stations.

Station Name	Sample Code	Pre-treatment Sample	Post-treatment Sample
City Entrance	A	A1	A2
Student Housing	B	B1	B2
Grand Mosque	C	C1	C2

A total of six samples were collected: three from the water source before desalination and three from the water produced after the desalination process.

Analytical Methods
The physicochemical properties of the water were measured before and after treatment using standard methods as detailed in the references [4, 5].

pH

The pH of the water samples was measured immediately after collection using a pH Meter, Model AR-50-HACH.

Electrical Conductivity (EC)

Electrical conductivity was measured in the field using an Electrical Conductivity Meter, Model AR-50-HACH. Readings were taken directly from the device's meter and were calculated in units of (μmhos.cm^{-1}) at 25 °C.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) were measured using a TDS meter, Model AR-50-HACH, and were calculated in units of (mg/L).

Calcium and Magnesium

Calcium and magnesium ions and hardness were determined in the water samples by the titration method, using an EDTA titration with E.B.T and Murexide indicators.

Sodium and Potassium

Sodium and potassium were measured using a Flame Photometer, Models PFP7 and PFP7/CJENWAY.

Nitrate

Nitrate concentrations in the water samples were determined using a Spectrophotometer, PU8625 Series UV/Visible PHILIPS, at a wavelength of λ=220 nm.

Chloride

Chloride was determined in the water using the titration method (Mohr) with a silver nitrate solution of known normality (0.05 N).

Bicarbonate

Bicarbonate was determined by titration with diluted HCl acid using a methyl orange indicator.

Sulfate

The turbidity method was used to measure the concentration of sulfates in the water samples using a Spectrophotometer, PU8625 Series UV/Visible PHILIPS. The absorbance of the sample and the standard curve was measured at a wavelength of λ=540 nm.

Statistical Analysis

The effectiveness of the desalination units in removing salts was measured by comparing the variables before and after treatment.

For the statistical analysis, the collected quantitative data were analyzed using the Statistical Package for the Social Sciences (SPSS) to check for statistically significant differences between the groups. An independent samples T-test and one-way analysis of variance (ANOVA) were used. The statistical significance level was set at [α=0.05].

Results and discussion

This The data in Table (2) shows the results of the analyses of the studied samples.

Table 2 Values of Water Properties Before and After Treatment for the Studied Stations.

Property	Sample Concentrations						Unit
	A1	A2	B1	B2	C1	C2	
PH	6.7	7.1	6.8	6.7	7.1	6.8	-
EC	480	485	156	151	164	464	µS/cm
T.D.S	307	310	99.8	96.6	104.9	296.9	mg/l
Sodium (Na+)	36.4	36.4	2	2	2.9	36.4	mg/l
Potassium (K+)	12	14	12	11	12	14	mg/l
Calcium (Ca++)	32	36	8	12	10	28	mg/l
Magnesium (Mg++)	14.4	2.4	7.2	8	6	12	mg/l
Chloride (Cl^-)	124.3	134.2	34.8	39.8	29.8	124.3	mg/l
Sulfate (SO_4^-)	18	17	8	7.4	7.5	14.4	mg/l
Bicarbonate (HCO_3^-)	79	109.8	103.7	115.9	97.6	122	mg/l
Nitrate (NO_3^-)	-	-	-	-	-	-	mg/l

Note: (-) indicates not detected.

pH

The results obtained, as shown in Figure (1), indicated that the pH values ranged from 6.7 to 7.1. Thus, all samples were within the permissible limits according to Libyan and international standards from the World Health Organization [6, 7]. The results of the statistical analysis also showed statistically significant differences in the average pH values at a significance level of 0.05, both between samples taken from different stations and between samples within the same station before and after treatment.

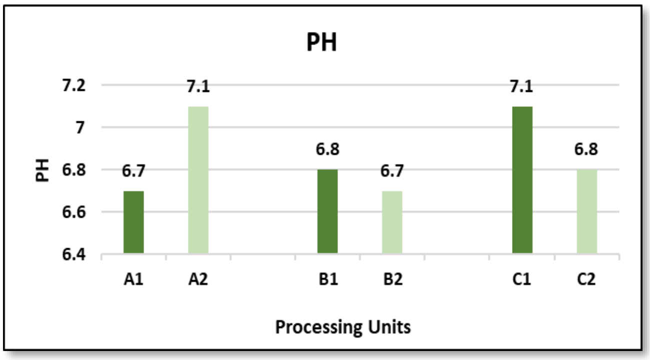

Figure 1: Comparison of Average pH Values.

Electrical Conductivity (EC)

The results obtained, as shown in the bar chart (2) for EC values, indicate that the highest values were recorded at station (A) before and after treatment, with values of 480 and 484 µS/cm, respectively. The statistical analysis results also showed significant differences in electrical conductivity between the studied samples, whether in the averages of the samples before or after treatment or between stations.

Contrary to expectations, it was noted that the electrical conductivity values for samples from stations (C and A) after treatment were higher than before treatment, especially at station (C), where the difference was somewhat large. Since electrical conductivity is the ability of water to conduct electricity as a result of the presence of calcium, magnesium, sodium, and potassium salts in the water [8], this may indicate a deficiency in the treatment unit. This could be due to a deterioration in the performance of the membranes used in the reverse osmosis process, which led to a decrease in their ability to reject ions like sodium and chloride, or due to a lack of regular maintenance and filter changes, among other operating requirements. In general, the recorded electrical conductivity values fall within the normal permissible range for drinking water according to the World Health Organization specifications [6], which is less than 2300 µS/cm. The Libyan Standard Specifications did not recommend a specific value.

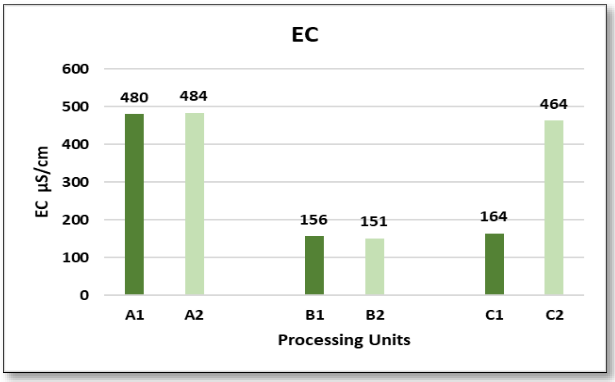

Figure 2: Comparison of Average Electrical Conductivity (EC) Values.

Total Dissolved Solids (TDS)

Figure (3) shows the results of the total dissolved solids test. Significant differences were observed in the total dissolved solids unit between the average studied samples, with values ranging between (96.6 and 310) mg/L. It was also noted that the total dissolved solids increased further after treatment for samples from stations (C and A), which may be attributed to a deficiency in the treatment unit. When comparing the values obtained with local and international standards, it was found that all concentrations did not exceed the permissible limits according to the Libyan Standard Specifications and the World Health Organization specifications [6, 7].

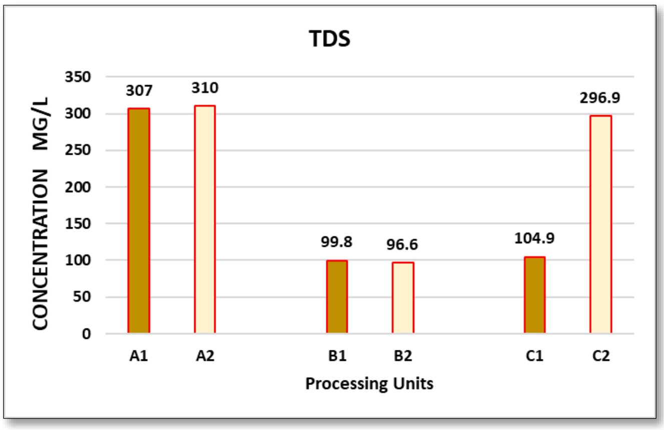

Figure 3: Comparison of Average Total Dissolved Solids (TDS) Values.

Sodium (Na+)

The data in Table (2) and Figure (4) show that the sodium concentrations in the samples ranged between 2 and 36.4 mg/L. This is within the permissible limits according to the World Health Organization and the Libyan Standard Specifications, which set the maximum permissible limit at 200 mg/L. The results of the statistical analysis also showed significant differences in the average sodium concentrations at a significance level of 0.05, either between samples from different stations or between samples within the same station before and after treatment. There was no change in sodium concentration before and after treatment for stations (A, B). In contrast, a significant increase was observed in the value recorded after treatment for station (C), which may explain the high EC and TDS results for the same sample. The presence of sodium in water is due to the rapid solubility of its salts and the abundance of its mineral deposits. The use of saline water may cause dehydration due to the imbalance it causes in the osmotic pressure between the stomach and intestines [9].

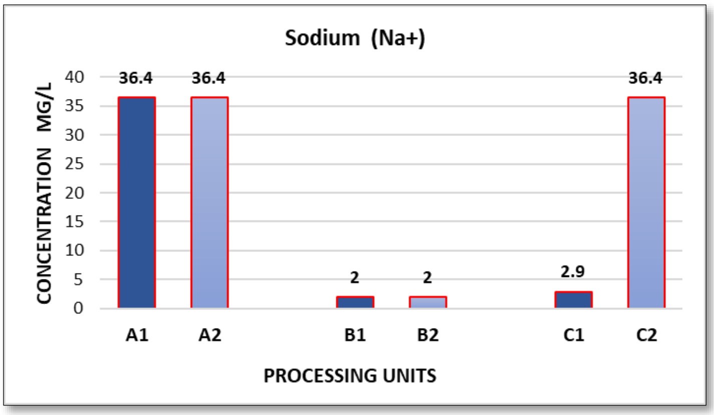

Figure 4: Comparison of Average Sodium (Na+) Values.

Potassium (K+)

The results of the potassium concentration analysis for the samples showed that the values ranged between 11 and 14 mg/L. This is within the permissible limits according to the Libyan Standard Specifications and the World Health Organization (WHO) standards [6, 7]. The results of the statistical analysis also showed no significant differences in potassium concentration at the same station before treatment in the three stations, while there were significant differences between the averages after treatment. Higher concentrations of potassium were also recorded after treatment at stations (A, C), which also explains the reasons for the high EC and TDS values for the same samples.

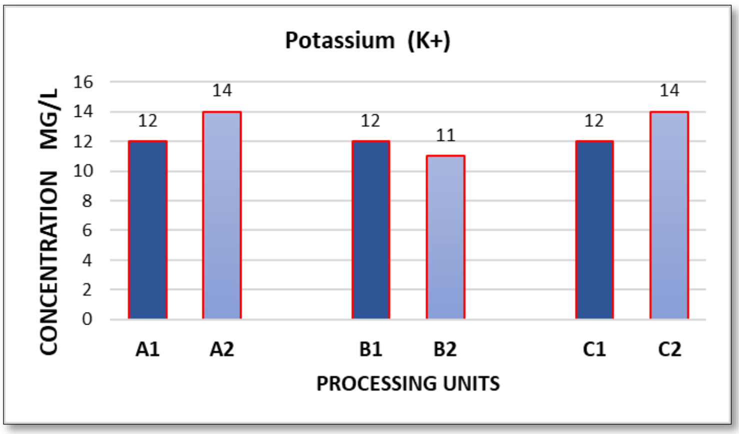

Figure 5: Comparison of Average Potassium (K+) Values.

Calcium (Ca++)

The data in Figure (6) showed that the calcium concentration values for the studied samples ranged between (8 and 36) mg/L. Thus, all obtained values did not exceed the permissible limits according to the Libyan Standard Specifications and World Health Organization specifications for calcium, which is 200 mg/L. We also note from the results of the statistical analysis that there were significant differences in calcium concentrations between the stations and also within the same station before and after treatment. The calcium concentrations in all stations after treatment were higher than the concentrations before treatment.

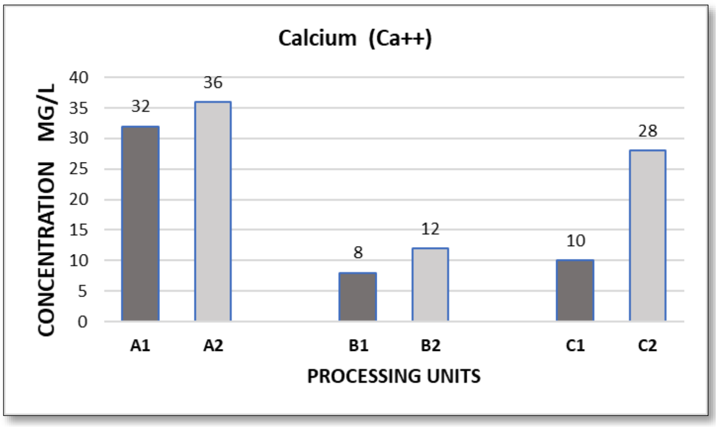

Figure 6: Comparison of Average Calcium (Ca++) Values.

Magnesium (Mg++)

The results obtained, as shown in Figure (7), showed that the magnesium concentrations in the studied samples ranged from (2.4 to 14.4) mg/L. Thus, all samples were within the permissible limits according to the Libyan and international standards from the World Health Organization. The results of the statistical analysis also showed significant differences in the average magnesium values at a significance level of 0.05, whether between samples taken from different stations or between samples within the same station before and after treatment. The magnesium concentrations in stations (B, C) after treatment were higher than before treatment.

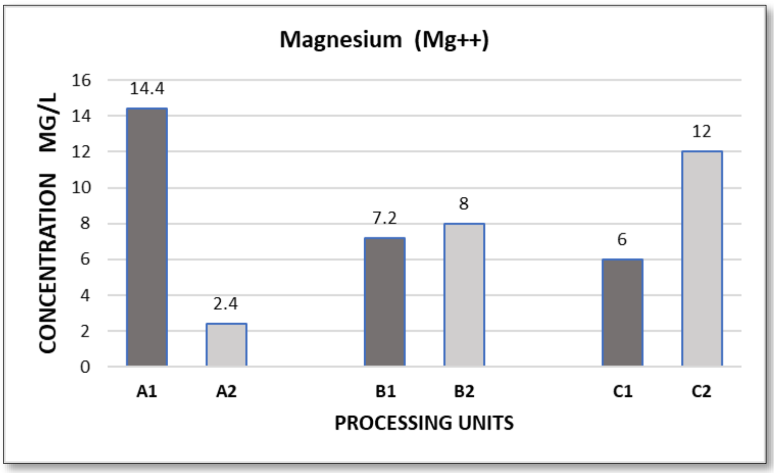

Figure 7: Comparison of Average Magnesium (Mg++) Values.

Chloride (Cl-)

The data shown in Figure (8) displays the chloride concentration for the studied stations. The highest value recorded was 134.2 mg/L at station (A) after treatment (A2), and the lowest value was at station (C) before treatment (C1) at 29.8 mg/L. Therefore, all recorded values are within the permissible limits according to the Libyan Standard Specifications for drinking water and the World Health Organization standards, which are specified as 250 mg/L. The results of the statistical analysis also showed statistically significant differences in chloride values for the stations before and after treatment, and between the different stations. The chloride concentrations in all stations after treatment were higher than the concentrations before treatment. Especially at station (C), where the difference was large: 29.8 mg/L before treatment and 124.3 mg/L after treatment. By comparing with the sodium values for the same samples, it can be concluded that most of the salts that may have caused the increase in EC and TDS are sodium chloride salts.

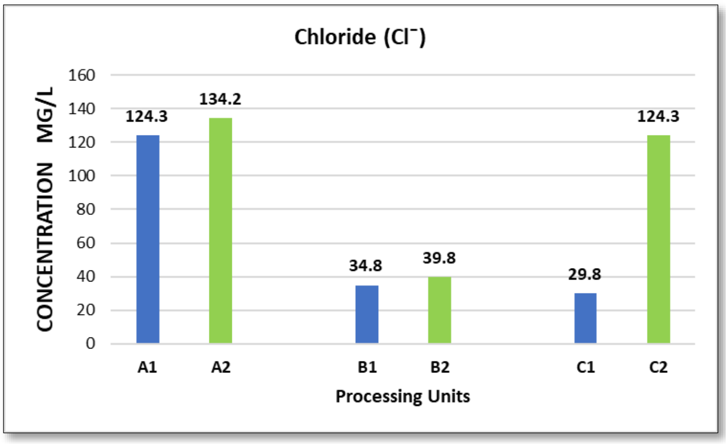

Figure 8: Comparison of Average Chloride (Cl-) Values.

Sulfate (SO4-2)

Figure (9) shows the sulfate concentration, where the lowest value was 7.4 mg/L at station (B) after treatment (B2), and the highest value was 18 mg/L at station (A) before treatment (A1). Thus, we find that all sulfate concentration values are below the maximum permissible limit of 400 mg/L according to the Libyan Standard Specifications and World Health Organization standards. The results also indicated significant differences between the studied stations before and after treatment, and between the three stations. We also note that the sulfate concentrations in both stations (A, B) were higher before treatment than after, while the sulfate concentration increased after treatment at station (C).

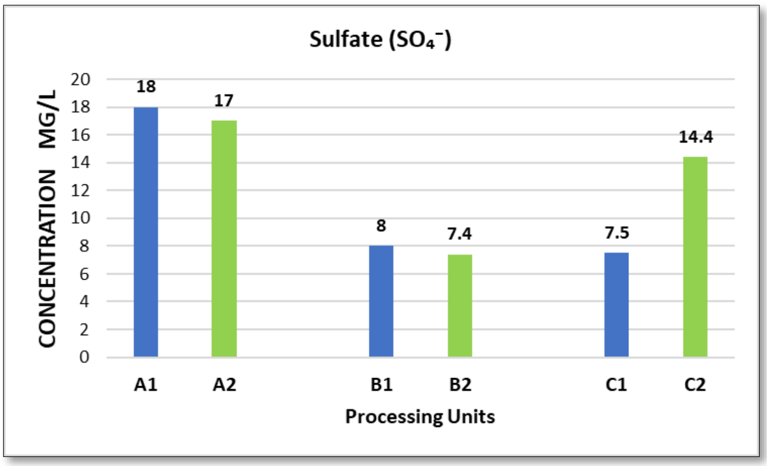

Figure 9: Comparison of Average Sulfate (SO_4--) Values.

Bicarbonate (HCO3-)

The results show a significant difference in bicarbonate concentrations between the stations and within the same station before and after treatment. Figure (10) shows the bicarbonate values, which ranged between 79 and 122 mg/L. Therefore, all obtained values are below the maximum permissible limit according to the World Health Organization specifications of 200 mg/L, while the Libyan Standard Specifications did not recommend a limit value for bicarbonate in drinking water. The bicarbonate concentrations in all stations after treatment were higher than the concentrations before treatment.

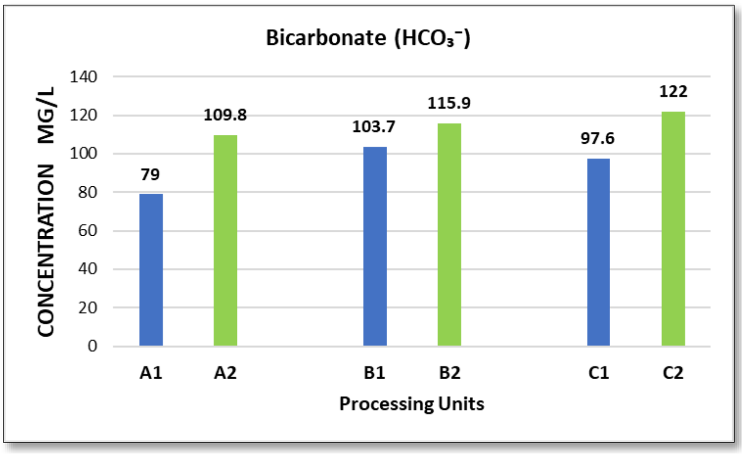

Figure 10: Comparison of Average Bicarbonate (HCO_3-) Values.

Nitrate (NO3-)

Based on the analysis results, it was found that the nitrate concentration in the water samples for all stations was lower than the device's sensitivity, which means that its concentration is very low or non-existent.

Conclusion

Based on the analysis of data from water samples from the decentralized treatment units in the city of Traghen, the following main conclusions can be summarized:
General Quality Standards: In general, the majority of the physicochemical properties of the water produced from the desalination units, such as pH and the concentrations of most major ions (sodium, potassium, calcium, magnesium, chloride, sulfates, and bicarbonates), are within the permissible limits according to Libyan and World Health Organization standards**.** Nitrate concentrations were also very low or undetectable.
Salt Removal Efficiency: Despite the overall positive results, the research revealed a significant variation in the efficiency of the desalination units in removing salts. This was evident in the increase in electrical conductivity

(EC) and total dissolved solids (TDS) values in some samples after treatment compared to before, especially at stations "A" and "C". This indicates that some units are not operating at optimal efficiency in reducing salinity as expected from desalination processes.
Potential Causes for Deficiency: The deficiency in salt removal efficiency in some units is likely due to technical reasons such as poor manufacturing or negligence in regular maintenance and the consistent replacement of filters and membranes. This lack of maintenance can lead to the deterioration of desalination membranes due to the expiration of their lifespan and a decline in their ability to effectively remove salts [10].
Need for Oversight and Quality Control: The results emphasize the urgent need to enhance oversight and supervision of these decentralized units to ensure they continuously produce water that meets health standards. The increasing reliance on them requires ensuring water quality to avoid any potential long-term health risks, even if the current levels are within permissible limits.
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Recommendations

Based on the results of this study, the following recommendations are presented to ensure the continued improvement of water quality and the sustainability of decentralized desalination units:

Conduct Periodic Monitoring: Regular monitoring of water quality is essential, especially for decentralized units, to ensure they consistently comply with local and international standards. This can be done by collecting and analyzing samples from all units periodically.

Implement Regular Maintenance Programs: It is crucial to establish a strict, scheduled maintenance program for these units, including the timely replacement of filters and membranes, to prevent the decline in their efficiency and performance.

Enhance Oversight and Regulation: There is a strong need to strengthen the regulatory role of relevant authorities to inspect and supervise these decentralized units. This includes setting clear standards for their operation and obligating owners to adhere to them.

Raise Public Awareness: Launch awareness campaigns to educate the public on the importance of checking water quality and the signs of unit malfunction. This will encourage citizens to take a more active role in ensuring their water source is safe.

Conduct Further Research: We recommend conducting more extensive research to cover a larger number of decentralized units in other regions of the country. This would provide a broader view of the effectiveness of these units on a national level.

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