Computational Water, Energy, and Environmental Engineering, 2024, 13, 1-12
https://www.scirp.org/journal/cweee
ISSN Online: 2168-1570
ISSN Print: 2168-1562

Study of Total Dissolved Solids (TDS) Concentrations Factor of SWCC Al-Khobar Plant Seawater Intakes

Ahmed Al-Kubaish, Jamal Salama, Waleed Al-Jurayan

Water Quality Section, Al-Khobar Production System, Saline Water Conversion Corporation, Al-Khobar, Saudi Arabia
Email: aalkubaish@swcc.gov.sa

How to cite this paper: Al-Kubaish, A., Salama, J. and Al-Jurayan, W. (2024) Study of Total Dissolved Solids (TDS) Concentrations Factor of SWCC Al-Khobar Plant Seawater Intakes. *Computational Water, Energy, and Environmental Engineering*, **13**, 1-12.
https://doi.org/10.4236/cweee.2024.131001

Received: October 15, 2023
Accepted: December 10, 2023
Published: December 13, 2023

Abstract

This study presents a significant contribution to the field of water quality assessment and sustainable water management practices. By evaluating the levels of total dissolved solids (TDS) in seawater intakes within Al-Khobar desalination production system, the study addresses a crucial aspect of water treatment and environmental impact assessment. The findings provide valuable insights into the variations and trends of TDS levels across different phases of the system, highlighting the importance of monitoring and management strategies. The study provided both gravimetric total dissolved solids (TDS) and electrical conductivity (EC) measurements to analyze TDS calculation factor and evaluate measurement accuracy. Results revealed significant variations in TDS levels across the sampling locations, with phase-2 exhibiting higher levels and greater fluctuations. Phase-3 displayed similar trends but with lower TDS levels, while phase-4 showed slightly different behavior with higher average TDS levels. EC measurements demonstrated a strong correlation with TDS, providing a reliable estimation. However, additional methods such as gravimetric analysis should be employed to confirm TDS measurements. The findings contribute to understanding water quality in the Al-Khobar desalination system, aiding in monitoring, management, and decision-making processes for water treatment and environmental impact assessment. The study enhances the credibility of water quality assessments and supports sustainable water management practices.

Keywords

Total Dissolved Solids, Conductivity, Seawater, Desalination

1. Introduction

Water is an essential and fundamental resource that is indispensable for the existence of all forms of life. The quality of water plays a critical role in safeguarding human health and preserving the environment. However, with the growing global demand for water, the availability of fresh water has become increasingly scarce in many regions. In order to overcome the water scarcity in areas with the less natural fresh water availability, desalination becomes a reliable and effective tool for providing a sufficient fresh water source [1]. The quality of the water used for desalination is an important factor in determining the process efficiency and product quality [2]. Water with high levels of impurities, such as suspended and dissolved solids, and organic matter can lead to fouling and scaling issues within the desalination system. These fouling and scaling phenomena can reduce the process efficiency, increase energy consumption, and potentially damage equipment, resulting in higher operational costs and decreased product quality [3].

In particular, the concentration of total dissolved solids (TDS) in seawater plays a vital role in desalination plants, particularly those utilizing Reverse Osmosis (RO) technology [4]. This advanced process involves forcing feedwater through a semi-permeable membrane to eliminate TDS. The performance of the desalination plant is significantly impacted by the TDS concentration in the feedwater [5]. Higher TDS levels pose challenges in removing salts and other substances, requiring more energy to pressurize the water flux through the membranes [6]. Therefore, it is crucial to comprehensively understand, continuously monitor, and effectively control the TDS levels of the feed water source to ensure the efficiency and effectiveness of water production.

In daily operation, the TDS level is typically reported using the electric conductivity (EC) ratio method [7]. The EC measure is the ability of water to conduct electrical charges, which comes from dissolved ions such as salts. It serves as an indicator of ion concentration in the solution. The more ions present in a water sample, the higher the EC results [8]. It is expressed in units of Micro Siemens per meter (μS/m). Total dissolved solids (TDS) combines all dissolved solids in the water, including the majority of salt ions and organic matter. TDS can be measured accurately using the gravimetric method [9] [10], which involves evaporating a measured volume of water and weighing the residue to determine the TDS level. However, this method is time-consuming and impractical for daily field operating and monitoring. As a result, the TDS level is typically calculated using an empirical factor derived from the relationship between the EC and TDS as mentioned in Rusydi review on 2018.

To further emphasizes the necessity of this research. It is significantly importance to focus on total dissolved solids (TDS) in the Arabian Gulf seawater. For addressing the concern of the gradual increase in TDS levels in Arabia Gulf over time, which has not been overlooked by previous studies. The reliance on the electrical conductivity (EC) factor for TDS measurement may not accurately capture the changes in seawater properties affecting TDS. Particularly for the operation of Reverse Osmosis (RO) plants, understanding and monitoring TDS levels accurately becomes critical.

In Khobar desalination production systems, there are three seawater intake areas: phase-2 (AK2/RO2), phase-3 (AK3), and phase-4 (RO1). The seawater TDS samples value observed to experience a gradually increase. The important of the change has become more essential and highlighted with the start of phase-4 (RO1) plant operation, which is the first RO plant in Al-Khobar plants. Knowing that seawater TDS can be change with time due to climatic and environmental aquatic conditions [11]. Thus, a recent studying of the TDS level in seawater is important for optimizing the design and operation of RO plants. By understanding the TDS level in seawater, it is possible to determine the required appropriate to reduce the TDS level and protect the membranes from fouling and scaling. Which reflects on optimize the operation, reduce maintenance costs, and ensure the production quality.

This paper present recent measurements of total dissolved solids (TDS) utilizing both the gravimetric method and electrical conductivity (EC) in seawater intakes for the Khobar desalination production system intakes; phase-2 (AK2), phase-3 (AK3), and phase-4 (RO1). The collected data is plotted to analyze and observe any trend changes across different locations. Additionally, the paper includes the calculation of the TDS factor, which is used to evaluate and verify the accuracy of the measurement method. By employing both techniques and assessing the TDS factor, the study aims to provide a comprehensive and reliable understanding of TDS levels in the Al-Khobar desalination production system, contributing to improved monitoring and management practices.

2. Methodology

The study analysis conducted by a group sample from Al-Khobar production system water quality section. The study focused on three sampling locations: AK2, AK3, and RO1 intakes sampling points. To ensure accurate and representative samples, continuous flow was maintained at all sample points to prevent contamination. Separate labeled bottles were used for each location, and qualified samplers collected the samples using the grab method. The collected samples were immediately transported to the main Khobar General Laboratory to minimize any physical changes.

Conductivity measurements were performed on the received samples using a calibrated WTW (Cond 7110) instrument. Standard solutions (1413 μS/cm and 12.88 mS/cm) were used to calibrate the instrument and ensure accuracy. To account for instrument precision, duplicate measurements of the samples were taken and averaged.

Before conducting TDS analysis, the samples were filtered using Ashless filter paper (110 mm, Ref. 300010) to remove suspended solids. A known volume (10 ml) of the filtered sample was transferred into a pre-weighed dish. The dish was then heated in an oven at 85˚C for 24 hours until complete dryness. Subsequently, the samples were heated for an additional hour at 180˚C to remove organics. After cooling in a desiccator, the samples were weighed to determine the weight of the residue. The TDS concentration was calculated by dividing the weight of the residue by the sample volume and expressed in parts per million (ppm).

To minimize personal selective errors, all laboratory analyses were performed by the same lab analyst. Additionally, the same instruments and apparatus were used for all samples to minimize errors caused by variations in lab equipment. The EC measurements were based on ASTM D1125-14, and the TDS analysis was conducted using the evaporation (gravimetric) method referenced in ASTM D5907-18 or ABHA 2540. The correlation between TDS and EC calculations was referenced from APHA 1030-E.

To further validate the study data, a portion of the randomly selected samples was sent to the Institute for Research, Water Technology Innovation Institute & Research Advancement (WTIIRA) for analysis, allowing for a comparison of results between the Al-Khobar study lab and WTIIRA, thereby enhancing the credibility of the study's findings.

3. Data

The study collected seawater samples from routine sample points at the SWCC Al-Khobar plant's intake for the AK2, AK3, and RO1 locations. Sampling was scheduled on a weekly basis, following the plant's operational status, with no emergency situations or shutdowns. Sample collection was suspended during vacation periods. All samples were taken in the morning between 9 to 10 AM for consistency across locations. TDS levels were measured using the gravimetric method, while EC measurements were conducted using the WTW (Cond 7110) lab conductivity meter. The TDS factor, or ratio, was calculated by dividing TDS (ppm) by EC (μS/cm).

The measurement results are presented in **Table 1**, which includes the average, standard deviation, maximum value, minimum value, and range for each measurement. To validate the main data, measurements were also conducted by the WTIIRA, and the corresponding data is listed in **Table 2**. The comparison between the Khobar lab and WTIIRA lab results is provided in **Table 3**. The evaluation aimed to ensure the validity of all data, minimize bias, and ensure reliable results.

One notable observation was that the measured TDS level at the RO1 site on July 5th, 2021, was below the seawater TDS level. Considering the EC value at this point, it indicated an invalid relationship between TDS and EC results, suggesting a potential error in the test performed by the analyst. Consequently, this particular data point was excluded from the analysis to ensure the accuracy of the remaining data in representing the seawater's TDS levels. The EC and TDS values for each site were plotted to assess the strength of the relationship and detect any data disruptions throughout the study period.

4. Result and Discussion

The present study aimed to investigate the levels of total dissolved solids (TDS) in the seawater intake of three locations within the SWCC Al-Khobar production system and analyze any potential differences among them. In this section, we present the results obtained from the TDS measurements conducted at each site. Descriptive statistics such as the mean, standard deviation, and range of the data are provided for each location. Furthermore, the data is visualized through various charts to facilitate a clear understanding and comparison between the three sites.

Table 1. TDS and EC measurements in SWCC Al-Khobar laboratory.

Date	Phase-2 (AK2)			Phase-3 (AK3)			Phase-4 (RO1)		
	EC (μS/cm)	TDS (ppm)	TDS factor	EC (μS/cm)	TDS (ppm)	TDS factor	EC (μS/cm)	TDS (ppm)	TDS factor
29.12.2020	64,000	50,000	0.781	64,300	50,000	0.778	65,600	51,000	0.777
18.01.2021	69,730	55,000	0.789	70,610	55,000	0.779	73,410	58,000	0.790
20.01.2021	69,540	55,000	0.791	70,850	54,000	0.762	73,300	59,000	0.805
25.01.2021	75,690	57,000	0.753	75,640	59,000	0.780	75,460	56,000	0.742
27.01.2021	75,460	57,000	0.755	75,710	57,000	0.753	75,780	58,000	0.765
03.02.2021	72,100	58,000	0.804	72,400	57,000	0.787	73,500	58,000	0.789
05.02.2021	72,000	56,000	0.778	72,500	58,000	0.800	73,500	58,000	0.789
09.02.2021	73,700	60,000	0.814	73,700	57,000	0.773	73,590	56,000	0.761
16.02.2021	68,000	55,000	0.809	68,800	55,000	0.799	70,900	55,000	0.776
01.03.2021	71,700	55,000	0.767	71,500	55,000	0.769	71,700	55,000	0.767
16.03.2021	74,200	55,000	0.741	74,500	56,000	0.752	74,600	56,000	0.751
03.04.2021	76,000	55,000	0.724	76,800	57,000	0.742	77,100	58,000	0.752
06.04.2021	78,100	60,000	0.768	78,100	58,000	0.743	78,200	61,000	0.780
05.07.2021	70,300	56,150	0.799	69,800	55,890	0.801	72,100	34,110*	0.473
12.07.2021	69,920	52,650	0.753	70,220	53,000	0.755	71,490	54,620	0.764
29.07.2021	71,500	57,050	0.798	72,000	57,380	0.797	72,900	58,810	0.807
03.08.2021	70,800	59,710	0.843	70,700	55,050	0.779	70,900	55,690	0.785
10.08.2021	67,200	53,630	0.798	67,600	53,780	0.796	68,300	54,590	0.799
16.08.2021	71,500	57,410	0.803	71,400	57,030	0.799	71,500	57,300	0.801
23.08.2021	68,300	54,440	0.797	68,800	54,990	0.799	69,200	55,470	0.802
25.08.2021	68,100	54,400	0.799	68,200	54,040	0.792	69,200	55,320	0.799
06.09.2021	68,600	54,160	0.790	69,300	54,420	0.785	68,700	54,170	0.789
14.09.2021	71,600	56,710	0.792	71,500	56,400	0.789	73,100	58,200	0.796
20.09.2021	68,400	52,390	0.766	68,000	52,530	0.773	69,400	53,560	0.772
30.09.2021	73,500	58,340	0.794	74,200	58,320	0.786	74,100	58,460	0.789
06.10.2021	67,000	52,300	0.781	67,600	52,390	0.775	67,900	52,640	0.775
12.10.2021	73,400	58,140	0.792	73,900	58,230	0.788	71,800	56,020	0.780
18.10.2021	70,200	55,800	0.795	72,200	57,460	0.796	72,100	56,800	0.788
25.10.2021	72,400	58,030	0.802	72,700	58,080	0.799	73,100	57,960	0.793

Continued

14.12.2021	72,700	58,690	0.807	72,900	58,800	0.807	71,900	57,940	0.806
21.12.2021	69,700	54,370	0.780	70,100	55,030	0.785	70,100	54,880	0.783
27.12.2021	72,000	57,550	0.799	72,200	57,560	0.797	72,500	57,430	0.792
04.01.2022	68,000	53,110	0.781	68,400	53,170	0.777	68,800	53,660	0.780
18.01.2022	68,200	53,090	0.778	69,200	53,860	0.778	70,400	55,580	0.789
25.01.2022	73,600	59,770	0.812	73,800	59,920	0.812	73,900	60,060	0.813
01.02.2022	72,200	57,830	0.801	72,000	57,980	0.805	71,100	56,480	0.794
07.02.2022	71,700	57,260	0.799	71,700	57,250	0.798	71,900	57,460	0.799
15.02.2022	72,600	57,560	0.793	72,400	57,560	0.795	73,300	58,320	0.796
20.02.2022	70,300	54,540	0.776	70,500	54,220	0.769	70,600	54,100	0.766
28.02.2022	69,000	53,800	0.780	69,600	53,930	0.775	71,400	55,550	0.778
02.01.2023	-	-	-	75,800	59,310	0.782	75,000	58,420	0.779
Average	71,074	55,922	0.787	71,515	55,990	0.783	72,018	56,417	0.784
St. Dev.	1985	2350	0.016	2782	2190	0.017	1827	2052	0.016
Minimum	67,000	50,000	0.753	67,600	50,000	0.742	67,900	51,000	0.742
Maximum	73,600	60,000	0.843	75,800	59,920	0.812	75,000	61,000	0.813
Range	6600	10,000	0.090	8200	9920	0.070	7100	10,000	0.071

Table 2. TDS and EC measurements by Water Technology Innovation Institute & Research Advancement (WTIIRA).

Date	Phase-2 (AK2)			Phase-3 (AK3)			Phase-4 (RO1)		
	EC (μS/cm)	TDS (ppm)	TDS factor	EC (μS/cm)	TDS (ppm)	TDS factor	EC (μS/cm)	TDS (ppm)	TDS factor
21.12.2021	67,370	53,040	0.787	67,590	53,200	0.787	67,370	53,580	0.795
27.12.2021	70,190	56,460	0.804	70,410	56,440	0.802	70,620	56,680	0.803
18.01.2022	67,940	52,100	0.767	68,060	52,860	0.777	70,250	54,860	0.781
07.02.2022	73,200	58,860	0.804	73,360	58,120	0.792	73,320	58,280	0.795
15.02.2022	74,330	58,760	0.791	74,640	58,580	0.785	74,580	59,200	0.794
Average	70,606	55,844	0.791	70,812	55,840	0.789	71,228	56,520	0.794

Table 3. Comparing between Khobar and WTIIRA lab results.

Date	Phase-2 (AK2)		Phase-3 (AK3)		Phase-4 (RO1)	
	TDS (%error)	TDS factor (%error)	TDS (%error)	TDS factor (%error)	TDS (%error)	TDS factor (%error)
21.12.2021	2.48%	0.92%	3.38%	0.26%	2.40%	1.57%
27.12.2021	1.91%	0.63%	1.96%	0.55%	1.31%	1.31%
18.01.2022	1.88%	1.50%	1.87%	0.21%	1.30%	1.09%
07.02.2022	2.76%	0.69%	1.51%	0.78%	1.42%	0.54%
15.02.2022	2.06%	0.29%	1.76%	1.29%	1.50%	0.23%
Average	2.22%	0.81%	2.10%	0.62%	1.59%	0.95%

The discussion encompasses an analysis of the potential sources of TDS in each site and how these sources may have influenced the observed TDS levels. By identifying the contributing factors, we can gain insights into the water quality of the three sites and understand the factors influencing TDS levels.

Firstly, the Khobar phase-2 (AK2) seawater plant's intake is currently the oldest operational intake within the Al-Khobar production system, starting its production phase in 1983. Table 1 shows that the mean TDS value at the AK2 site was 55,922 ppm, with a standard deviation of 2350 ppm. The maximum TDS value was observed in the first week of February and April, reaching 60,000 ppm, while the lowest value of 50,000 ppm was recorded in mid-December. These results indicate significant variations in TDS levels throughout the year. Figure 1 also demonstrates the high fluctuation in TDS values at the AK2 seawater intake. One possible explanation for this instability is that the AK2 intake pipes are located close to the shore, making them susceptible to external activities or effluent discharge from nearby plants. Additionally, the average seawater TDS calculation factor for AK2 was found to be 0.787, the highest factor compared to the other locations. The data disruption shown in Figure 2 indicates a high degree of variability, likely influenced by the natural conditions of the site and its proximity to the coast.

Secondly, the data from phase-3 intake shows relatively lower seawater TDS levels compared to the other intakes, with an average of 55,862 ppm. The maximum TDS value recorded was 59,920 ppm on January 25th, which coincides with the maximum sample value at AK2. Similarly, the minimum TDS value was observed around the same time as AK2, during the first week of October (Table 1). Figure 1 supports the notion that the TDS trends of AK2 and AK3 are similar due to their close proximity. However, AK2's trend exhibits more fluctuations, which further supports the influence of natural events and other circumstances near the shoreline. The relationship between EC and TDS in AK3 is stronger compared to the other locations, as depicted in Figure 3, which shows a more linear relationship with a slope of 0.7827.

Thirdly, the RO1 intake is approximately 2 kilometers east of the phase, refer to Figure 4, which is a longer distance compared to the other Khobar intakes. This distance is reflected in the RO1 data, resulting in slightly different behavior compared to AK2 and AK3. The average TDS level at RO1 was 56,417 ppm, the highest among the sampled points. The highest TDS value of 61,000 ppm was observed in April, while the lowest concentration of 51,000 ppm was recorded at the end of December. The standard deviation of TDS was calculated to be 2052 ppm. The high seawater TDS level in RO1 can be attributed to location's geometry falls within a narrow strait, making it more susceptible to the influence of seawater currents and disturbances caused by infrastructure activities and organic sources. Figure 5 illustrates that the pattern reflection change of RO1 TDS occurs earlier than AK2 and AK3, indicating that seawater currents have a greater effect on RO1 before reaching AK2 and AK3. The relationship between

EC and TDS in RO1 shows a weaker regression strength compared to AK3. However, the data disruption along the linear trendline is closer compared to AK2, providing further support for the influence of seawater currents on RO1.

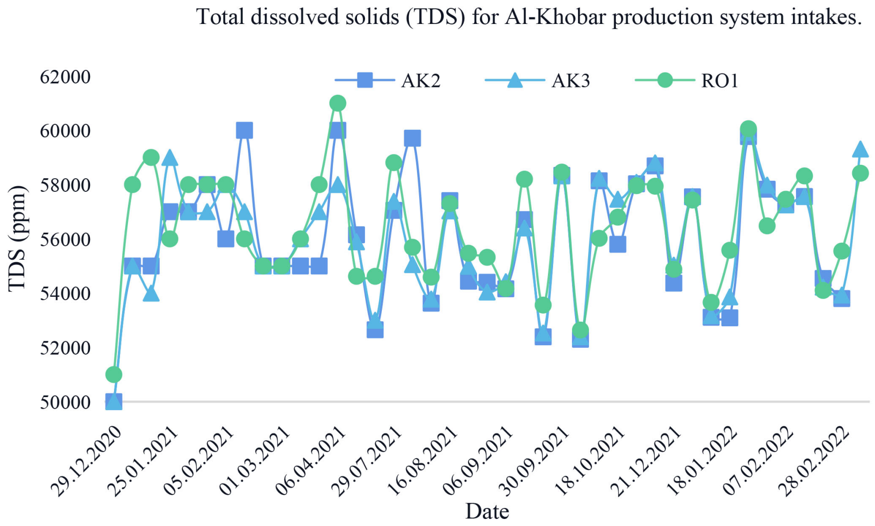

Figure 1. Total dissolved solids (TDS) for Al-Khobar production system intakes.

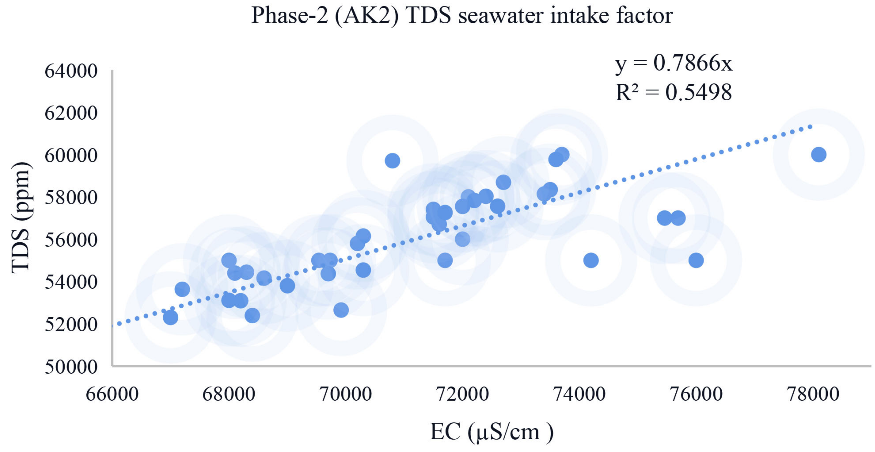

Figure 2. AK2 TDS factor measurements.

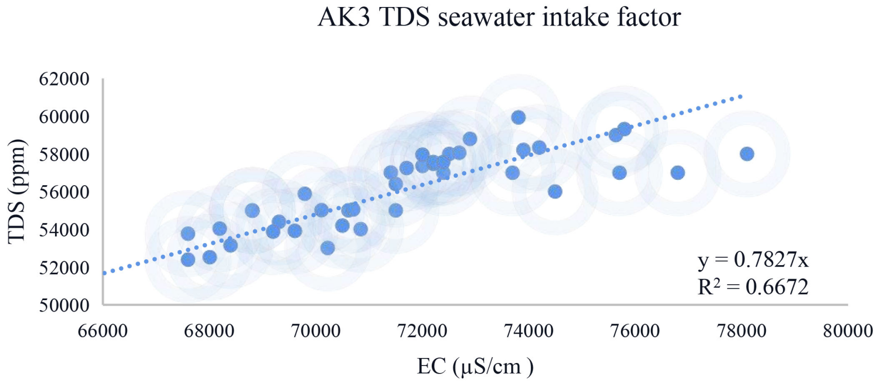

Figure 3. Total dissolved solids (TDS) for Al-Khobar production system intakes.

Figure 4. Al-Khobar approximate intakes location [12].

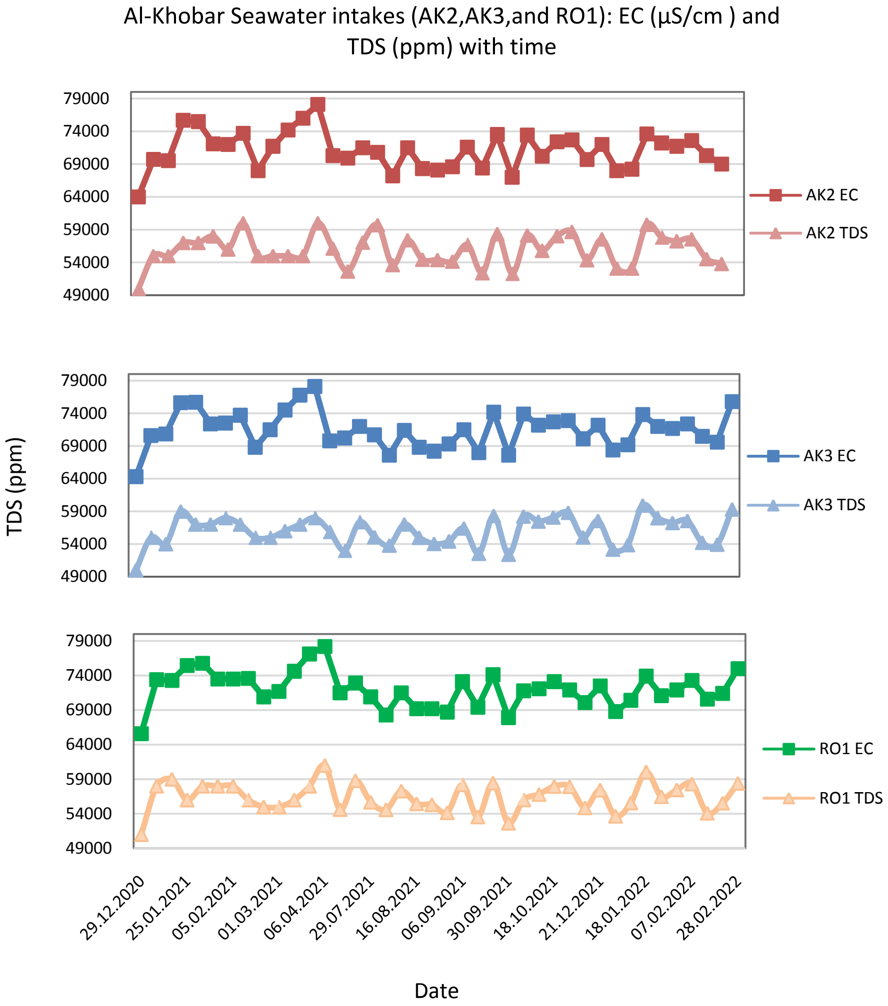

Figure 5. Total dissolved solids (TDS) for Al-Khobar production system intakes.

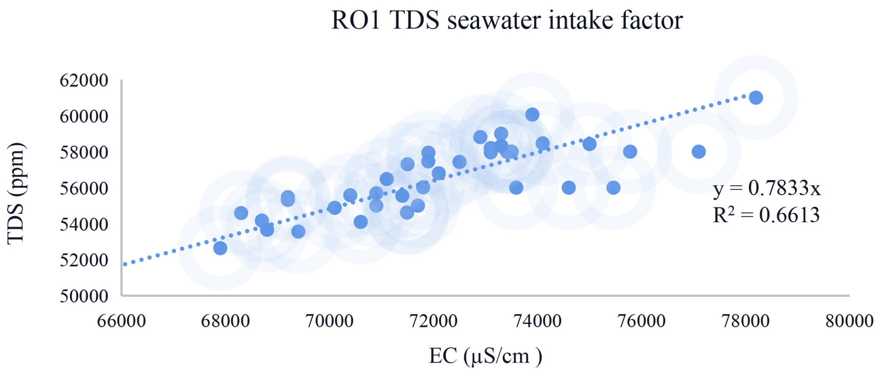

Figure 6. Total dissolved solids (TDS) for Al-Khobar production system intakes.

Regarding TDS-to-EC Ratio, electric conductivity is influenced by the type and concentration of ions present in the solution. On the other hand, TDS levels encompass not only ions but also other dissolved solids, including organic compounds, minerals, and other substances that are not electrically charged. Therefore, a solution with a high TDS may not necessarily exhibit high electrical conductivity if the majority of dissolved substances are non-ionic, and vice versa.

To establish the liner relationship between electrical conductivity (EC) and total dissolved solids (TDS), the measured EC data was plotted against TDS levels over time for all Al-Khobar intake locations, as shown in **Figure 2**, **Figure 3**, **Figure 6**. These graphs provide strong visual evidence of the relationship between conductivity and TDS. Consequently, EC is widely considered a reliable means of estimating calculated TDS. The average factor for all Al-Khobar intakes is 0.79, so TDS (ppm) = 0.79 × Conductivity measurement (µS/cm).

From **Figure 5**, the overall shape of the EC and TDS trends displays a similar pattern. It is observed that the EC patterns show less reaction to high spikes in TDS levels, such as those observed at the beginning of April. This can be explained by the fact that the increase in TDS during that season is primarily due to high concentrations of organic compounds, which are not accurately reflected in EC measurements.

It is important to recognize the limitations of using EC as a proxy for TDS, particularly has limitations due to interference from other ions, temperature dependency, inability to detect non-conductive substances, calibration issues, and variability in sample composition. While EC provides a valuable estimation of TDS, additional analysis and consideration of other factors are necessary to fully understand the composition and sources of TDS in seawater intakes. It is recommended to use EC as a screening tool and confirm TDS measurements using other methods, such as gravimetric analysis, to ensure accuracy.

5. Conclusions

In conclusion, this study aimed to assess the levels of total dissolved solids (TDS) in seawater intakes at three locations within the Khobar desalination production system, AK2 (RO2), AK3, and RO1. The study employed both the gravimetric method and electrical conductivity (EC) measurements to analyze TDS levels and evaluate the accuracy of the measurement techniques. The TDS factor, calculated by dividing TDS by EC, was used to establish the relationship between the two measurements.

The results of the study showed significant variations in TDS levels across the three sampling locations throughout the year. AK2, being the oldest operational intake, exhibited higher TDS levels compared to the other sites, with notable fluctuations. The proximity of AK2 to the shore and potential external activities or effluent discharge from nearby plants could contribute to the observed instability. AK3, located close to AK2, displayed similar TDS trends but with relatively lower levels. The RO1 intake, situated at a greater distance, showed slightly different behavior, with higher average TDS levels, possibly influenced by seawater currents and disturbances from infrastructure activities.

The analysis demonstrated a strong correlation between EC and TDS measurements, with EC serving as a reliable estimation of TDS levels. However, it is important to note that EC may not accurately reflect non-ionic dissolved substances and organic compounds, which can contribute to high TDS levels. Therefore, additional methods, such as gravimetric analysis, should be employed to confirm TDS measurements and ensure accuracy.

The findings of this study provide valuable insights into the water quality of the Al-Khobar desalination production system. The information can be utilized to improve monitoring and management practices, guide decision-making processes related to water treatment strategies, and assess environmental impacts. By understanding the sources and variations of TDS levels, appropriate measures can be implemented to maintain optimal water quality and ensure the efficient operation of the desalination production system.

Acknowledgements

We gratefully acknowledge that the data used in this study is owned by our organization, Saline Water Conversion Corporation, Al-Khobar production system. We appreciate the efforts and resources invested in collecting and maintaining the data, which has been instrumental in conducting this research. This study would not have been possible without the ownership and support provided by our organization.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ghaffour, N., Missimer, T.M. and Amy, G.L. (2013) Technical Review and Evaluation of the Economics of Water Desalination: Current and Future Challenges for Better Water Supply Sustainability. *Desalination*, **309**, 197-207.

https://doi.org/10.1016/j.desal.2012.10.015

[2] Azadi, F., Ashofteh, A. and Loaiciga, H. (2019) Reservoir Water-Quality Projections under Climate Change Conditions. *Water Resources Management*, **33**, 401-421. https://www.researchgate.net/publication/327893093_Reservoir_Water-Quality_Projections_under_Climate-Change_Conditions

[3] Matin, A., Laoui, T., Falath, W. and Farooque, M. (2021) Fouling Control in Reverse Osmosis for Water Desalination & Reuse: Current Practices & Emerging Environment-Friendly Technologies. *Science of the Total Environment*, **765**, Article 142721. https://doi.org/10.1016/j.scitotenv.2020.142721

[4] Saeed, M.O., Al-Nomazi, M.A. and Al-Amoudi, A.S. (2019) Evaluating Suitability of Source Water for a Proposed SWRO Plant Location. *Heliyon*, **5**, e01119. https://doi.org/10.1016/j.heliyon.2019.e01119

[5] Younos, T. (2005) The Economics of Desalination. *Journal of Contemporary Water Research & Education*, **132**, 39-45. https://core.ac.uk/download/pdf/60532478.pdf https://doi.org/10.1111/j.1936-704X.2005.mp132001006.x

[6] Pushpalatha, N., Sreeja, V., Karthik, R. and Saravanan, G. (2021) Total Dissolved Solids and Their Removal Techniques. *International Journal of Environmental Sustainability and Protection*, **2**, 13-30. https://doi.org/10.35745/ijesp2022v02.02.0002 https://www.researchgate.net/publication/367610659_Total_Dissolved_Solids_and_Their_Removal_Techniques

[7] Rusydi, A.F. (2018) Correlation between Conductivity and Total Dissolved Solid in Various Type of Water: A Review. *IOP Conference Series: Earth and Environmental Science*, **118**, Article 012019. https://doi.org/10.1088/1755-1315/118/1/012019

[8] Walton, N.R.G. (1989) Electrical Conductivity and Total Dissolved Solids—What Is Their Precise Relationship? *Desalination*, **72**, 275-292. https://doi.org/10.1016/0011-9164(89)80012-8

[9] ASTM International (2018) D5907-18: Standard Test Methods for Filterable Matter (Total Dissolved Solids) and Nonfilterable Matter (Total Suspended Solids) in Water. https://www.astm.org/d5907-18.html

[10] Standard Methods Committee of the American Public Health Association, American Water Works Association and Water Environment Federation (2023) 2540 SOLIDS. In: Lipps, W.C., Baxter, T.E. and Braun-Howland, E., Eds., *Standard Methods for the Examination of Water and Wastewater*, APHA Press, Washington, DC, 66-72.

[11] Younos, T. and Tulou, K.E. (2005) Overview of Desalination Techniques. *Journal of Contemporary Water Research & Education*, **135**, 15-22. https://core.ac.uk/reader/60532470 https://doi.org/10.1111/j.1936-704X.2005.mp132001002.x

[12] Google Earth (2023) Google Earth Web Version. https://earth.google.com/