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Environmental Study for Seawater Quality to Assess the Ecological Risks of Marine Environment in Arabian Gulf Region

Ahmed Ata, Mohamed Gad, Salah Elsayed, Mohamed K. Fattah and Ezzat Elfadaly

Environmental Studies and Research Institute, University of Sadat City, Egypt

Abstract

Seawater quality near Mesaieed Industrial City (MIC) has deteriorated in recent years due to rapid, unplanned petroleum industry development, impacting the marine ecosystem. This study aims to enhance seawater quality assessments and identify environmental factors affecting MIC's marine environment. Seawater samples were collected from 23 locations in 2022 and 2023 across summer and winter (top-bottom), and 17 physiochemical parameters and heavy metals including Chlorophyll 'a', NH3, NO3, NO2, TP, Cr-VI, Al, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, and Zn. were analysed reveals contamination across various levels, with certain elements such as NO3, NH3, NO2, and Chlorophyll 'a' significantly affecting water quality, while other parameters showed moderate effects. These measurements were used to calculate Arithmetic Water Quality Index (AWQI) scores, which indicate a high level of pollution, posing serious ecological risks for MIC's marine environment. Findings suggest that untreated brine discharge and treated industrial wastewater (TIW) are the primary pollutants, contributing to elevated levels of key contaminants. Additionally, rising salinity has exacerbated seawater degradation, further threatening marine life. The study underscores the need for stricter industrial wastewater management and advanced treatment methods before discharging effluents into the seawater to reduce ecological harm. To address these findings, regulatory measures must be implemented to mitigate industrial drainage, ensuring better protection for MIC's aquatic ecosystem and preserving the seawater's environmental quality.

Keywords: Seawater Quality, Industrial Treated Wastewater, Petroleum Industries, Water Quality Index.

Introduction

Industrialisation and unchecked urbanisation have significantly altered the natural environment. The most diverse, dynamic, and productive ecosystems on Earth are found in seawater. The physiochemical components and the biological community, as well as their interactions, comprise the aquatic ecosystem. The aquatic environment is a complicated web of biological and physical processes, and changes don't happen in an empty space **(Shakweer et al., 2005).** On the other hand, an ecosystem has often evolved over time, with species becoming adapted to their surroundings **(Shakweer et al., 2005; Rakib et al., 2021)**. Seawater quality indicators have received a lot of attention in recent years in water environment research because of the potential for toxic effects, persistence, and bioaccumulation issues that can harm aquatic ecosystems **(Carr et al., 2006; Censi et al., 2006).** Petroleum industries activities, several, industrial operation, and urbanization processes can pollute the environment and lead to water ecosystem contamination, endangering aquatic biota and humans **(Doherty et al., 2010).** Water quality is a crucial component of Seawater management, thus evaluating seawater quality for aquatic environments in developing nations is a critical issue in recent times **(El-Zeiny et al., 2019)**. The seawater area around Mesaieed Industrial City (MIC), which is near the majority of the petroleum companies there and acts as a major reservoir for the outflow of industrially treated wastewater in Mesaieed, is one of Qatar's most significant sea-aquatic ecosystems. The marine environment is a popular spot for fishing, tourists, and migratory birds in the summer and winter **(Fouda et al., 2012).** The Arabian Gulf region has long been a pivotal player in the global petroleum industries, contributing significantly to the world's energy demands. This economic prominence, however, comes with a complex environmental challenge. The disposal of treated industrial wastewater from petroleum facilities into the delicate ecosystem of the Arabian Gulf. This Research presents a comprehensive Environmental Impact Assessment (EIA) study aimed at evaluating the consequences of discharging treated industrial wastewater into the Arabian Gulf water, with a focus on the potential ecological, chemical, and biological impacts on the marine environment **(ESC, Qatar University. 2008-2010.Marine Survey Report)**. The petroleum industry is renowned for its intricate operations, which encompasses the extraction, refinement, and distribution of hydrocarbon resources. In the process, substantial quantities of industrial wastewater are generated, necessitating treatment before the release into the surrounding environment. The Arabian Gulf, with its strategic location and vast reserves of oil and gas, has become a hotspot for petroleum-related activities. Consequently, the Gulf's marine ecosystem is subjected to continuous exposure to treated industrial wastewater effluents, raising concerns about the long-term sustainability of this fragile environment. **(ESC, Qatar University. 2008-2010. Marine Survey Report).** Natural and human processes, along with the transfer of nutrients and trace elements to surface waters, significantly affect water quality in any region **(Zhao et al., 2019)**. Water quality indices (WQIs) are crucial in this process, which are considered a communication tool for transferring water quality data and should be calculated to monitor water quality **(Ball et al., 1980; Kamboj et al., 2020)**. The WAWQI is an arithmetic weighted technique for classifying water quality based on purity levels **(Brown et al., 1972).** To calculate these indices by tradition equations methods, require several steps, accuracy in the calculation, time and high effort to convert a large number of water characterization data into a single value of (WAWQI) to describe the level of water quality **(Brown et al., 1972; Tamasi et al., 2004).** To the best of our knowledge, little research has predicting WQIs using water characterization data. This study was driven by the urgency to address the knowledge gaps surrounding the environmental implications of discharging treated industrial wastewater into the Arabian Gulf. By conducting a rigorous EIA, this research intends to assess the potential risks and benefits associated with this practice, with a particular emphasis on safeguarding the Gulf's unique biodiversity, maintaining water quality, and preserving the delicate balance of its ecosystems **(ESC, Qatar University. 2008-2010.Marine Survey Report).** To bolster the credibility and reliability of this assessment, the research drew upon a wealth of scientific research, environmental impact studies, and regulatory documents. Key references, such as the works of **(Al-Yamani, 2017)** on the Gulf's biodiversity and the comprehensive review by Ministry of Environment and Climate Affairs **(MECA, 2019)** on industrial wastewater management, will be pivotal in constructing a well-informed analysis of the situation. These references, among others, served as the foundation upon which this Research was built, ensuring that the conclusions drawn were firmly grounded in established scientific knowledge and environmental policies **(ESC, Qatar University. 2008-2010.Marine Survey Report)**. The Physicochemical parameters such as temperature, pH, salinity, and trace elements like Chlorophyll 'a', NH3, NO3, TP, (Cr-VI), AL, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, and Zn are key indicators and essential markers of water quality, playing a crucial role in determining water suitability for aquatic life. An increase in trace elements above the quantification limit can negatively impact water quality, damaging both the environment and anthropogenic activities **(Hum. Ecol. Risk Assess., 2017 and Environ. Monit. Assess., 2019)** and Heavy metals such as Zn, while vital for living organisms, become toxic in excessive amounts **(Ecol. Modell., 2011).** Therefore, The Objectives of this work to evaluate and predict the contamination risks of (AWQI) to describe the level of water quality for seawater due to heavy metals effect to seawater quality. This Research represented a critical step towards a more sustainable future for the Arabian Gulf region, by shedding light on the potential environmental impacts of treated industrial wastewater discharges, the research aimed to inform decision-makers, industry stakeholders, and environmentalists alike. Through this research, aspired to foster a deeper understanding of the delicate balance between economic development and environmental conservation, ultimately paving the way for responsible and ecologically sound practices within the petroleum industries in the Arabian Gulf Region.

Materials and methods

Study area

Mesaieed is an industrial city in Al Wakrah Municipality in the State of Qatar, approximately 36 kilometres (22 mi) south of Doha with coordinates **24.9820° N, 51.5526° E.** It was one of the most important cities in Qatar during the 20th century, having gained in recognition as a prime industrial zone and tanking center for petroleum received from Dukhan.Both Mesaieed and its industrial area were administered by a subdivision of “QatarEnergy” called "Mesaieed Industry City (MIC) Management", which was established in 1996.

Mesaieed was established in 1949 as a simple port facility and since then has grown to support a wide range of major industries. The accelerated industrial and urban expansion within MIC which has constituted stressors for the natural environment, particularly in terms of marine water quality and associated sensitive habitats, through the discharge of industrial wastewater streams. The case study at MIC marine area Fig. 1. assessed the impact of Treated Industrial Wastewater (TIW) and brine discharge to sea via sampling and dispersion modelling. The model ran to be identified the potential impact area of the TIW and brine streams in the receiving water of the Arabian Gulf and identify mitigation measures.

Sampling and Analysis

Samples of seawater were collected from 23 different places across Mesaieed Industrial City (MIC) surrounding water during summer (Top / Bottom) samples and winter (Top / Bottom) samples over two years 2022 and 2023.

A sampling points and plan for the field survey was provided in Fig. 2. and Table 1. while a detailed methodology for the sampling was provided in Sampling and Analysis part. Sampling and measurements for all locations were scheduled on the same day, dependent on favourable weather and tidal conditions. Sampling was divided into two days due to large number of sampling locations, hence one-day sampling for low tide were done followed by a high tide sampling.

The results are displayed in Table 2. In order to improve data confidence from the analytical process, duplicates were carried out throughout the analysis for quality assurance and quality control (QA/QC) of the surface water samples. Additionally, the accuracy of the technique was ensured by testing certified reference materials (ERM-CA713).

The samples were collected following standard protocols as outlined in the American Public Health Association **(APHA Guidelines, 2017)**. Using a portable MAGELLAN GPS 315, UTM coordinates were used to pinpoint the position of the samples that were gathered. as seen in Field Sampling Locations and Measuring Points, Fig. 3.

Using a calibrated YSI Professional Plus portable multi-parameter analyser (Hanna HI 9811-5), physical characteristics of the water samples, including salinity, pH, and T ◦ C, were determined in situ. Seawater samples were collected in 500 mL plastic bottles that were labelled beforehand and acidified with nitric acid to a pH of less than 2. The bottles were promptly sealed and kept in a refrigerator at 4 °C until they could be examined further. standard methods for analysis **(APHA Guidelines, 2017).** were used to analyze trace elements such as Chlorophyll 'a', and NH3 measured by using Quantified method of a Hach DR6000 spectrophotometer, but for NO3, NO2, TP, (Cr-VI), AL, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, and Zn using an inductively coupled plasma mass spectrometer (Thermo Fisher Scientific Inc., Waltham, MA, USA; ICAP TQ ICP-MS). Following chain of custody paperwork, the samples were sent to EXOVA L.L.C. Doha, Qatar, an authorised laboratory, for examination.

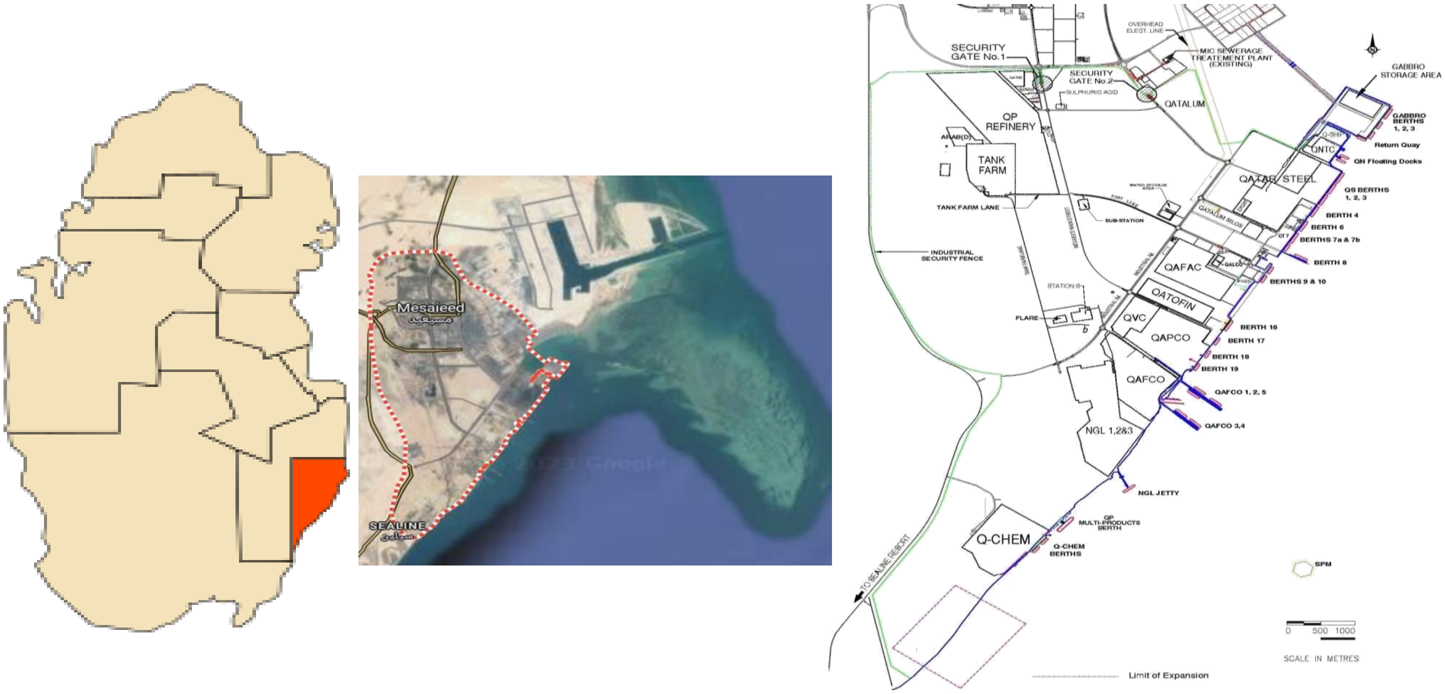
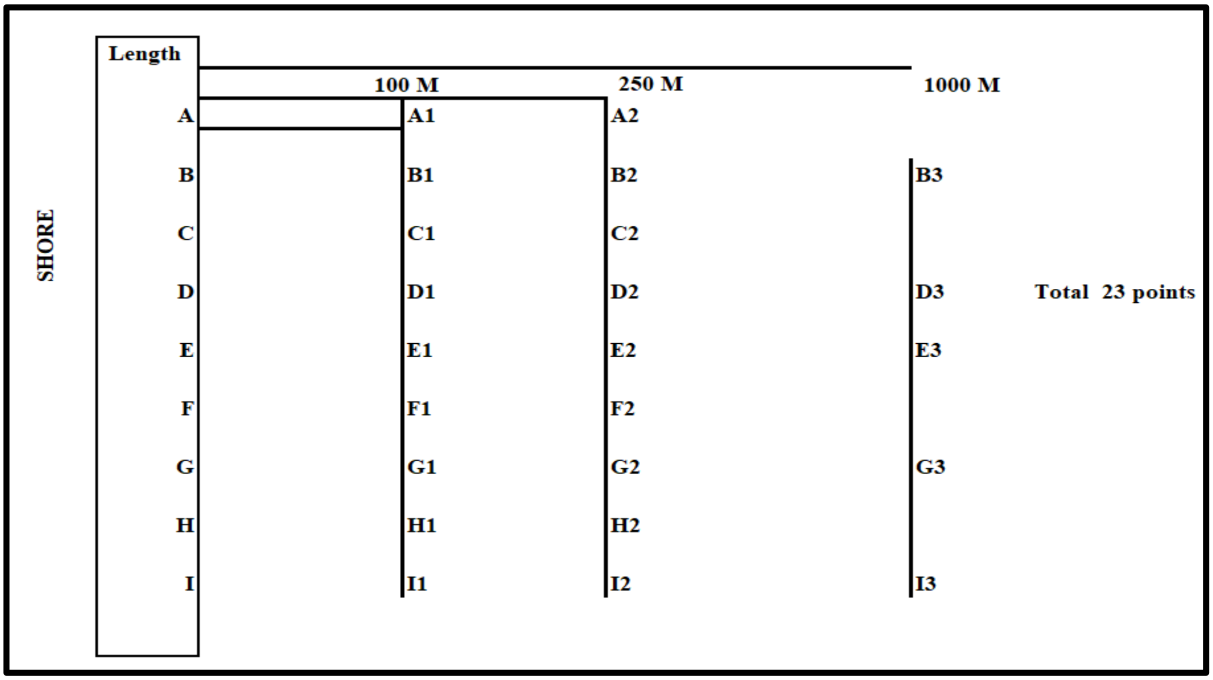


Fig. 1. Location of the Study Area.



Length	100 M	250 M	1000 M
A	A1	A2	
B	B1	B2	B3
C	C1	C2	
D	D1	D2	D3
E	E1	E2	E3
F	F1	F2	
G	G1	G2	G3
H	H1	H2	
I	I1	I2	I3

Total 23 points

Fig. 2. Sampling Points.

Table 1. Sampling Plan and coordinates locations.

No.	**Sampling Locations**	**Coordinates**		**Summer Sampling**	**Winter Sampling**	**High Tide**	**Low Tide**	**In-Situ Analysis**	**Laboratory Analysis**
		X	**Y**						
1	**A1**	**238855**	**356934**	√	√	√	√	√	√
2	**B1**	**238989**	**356867**	√	√	√	√	√	√
3	**C1**	**237999**	**355478**	√	√	√	√	√	√
4	**D1**	**238134**	**355411**	√	√	√	√	√	√
5	**E1**	**238631**	**354854**	√	√	√	√	√	√
6	**F1**	**237404**	**354461**	√	√	√	√	√	√
7	**G1**	**237534**	**354386**	√	√	√	√	√	√
8	**H1**	**236754**	**353489**	√	√	√	√	√	√
9	**I1**	**236888**	**353422**	√	√	√	√	√	√
10	**A2**	**237359**	**352898**	√	√	√	√	√	√
11	**B2**	**236185**	**352380**	√	√	√	√	√	√
12	**C2**	**236313**	**352301**	√	√	√	√	√	√
13	**D2**	**236836**	**351763**	√	√	√	√	√	√
14	**E2**	**235638**	**351579**	√	√	√	√	√	√
15	**F2**	**235757**	**351487**	√	√	√	√	√	√
16	**G2**	**234931**	**350241**	√	√	√	√	√	√
17	**H2**	**235054**	**350157**	√	√	√	√	√	√
18	**I2**	**235323**	**349449**	√	√	√	√	√	√
19	**B3**	**234100**	**349390**	√	√	√	√	√	√
20	**D3**	**234222**	**349302**	√	√	√	√	√	√
21	**E3**	**233486**	**348547**	√	√	√	√	√	√
22	**G3**	**233608**	**348460**	√	√	√	√	√	√
23	**I3**	**234222**	**347985**	√	√	√	√	√	√

Weighted Arithmetic Water Quality Index (WAWQI)

The most commonly measured water quality criteria are used by the WAWQI to evaluate the degree of purity of the water. The WAWQI, which is calculated mathematically using the formula given by **(Brown et al., 1972)** is the best index for assessing the general quality of surface water for aquatic use. Equation (1) is utilised to calculate the WAWQI using the weighted arithmetic approach:

$$\mathrm{AWQI} = \sum_{i=1}^{n} Q_i W_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Table 2. The AWQI calculations for the seawater parameters on the present research.

Water Quality Parameters 2022-2023				
Parameters	**Aquatic Life***	**Arithmetic Weight (W_i)**	**Sub-Quality Index (Q_i)**	**WAWQI**
Chlorophyll 'a'	0.01	0.008057456	120	0.966894725
Nitrogen (Ammonia)	1	8.05746E-05	2.1	0.000169207
Nitrate (NO_3)	2.93	2.74998E-05	7.610921502	0.000209299
Nitrite (NO_2)	0.06	0.001342909	28.33333333	0.038049098
Phosphorus (Total)	0.05	0.001611491	22	0.035452807
Chromium (VI)	0.0015	0.053716374	10	0.537163736
Aluminium (Al)	0.1	0.000805746	3.9	0.003142408
Barium (Ba)	0.05	0.001611491	22	0.035452807
Cadmium (Cd)	0.001	0.08057456	110	8.863201643
Chromium (Cr)	0.01	0.008057456	101	0.81380306
Copper (Cu)	0.004	0.02014364	12.5	0.251795501
Iron (Fe)	0.3	0.000268582	2.333333333	0.000626691
Lead (Pb)	0.007	0.011510651	1.428571429	0.016443788
Manganese (Mn)	0.05	0.001611491	2.2	0.003545281
Mercury (Hg)	0.0001	0.805745604	100	80.57456039
Nickel (Ni)	0.025	0.003222982	0.4	0.001289193
Zinc (Zn)	0.05	0.001611491	22	0.035452807
		$\sum w_i = 1$		

* All physicochemical parameters are expressed in mg/L.

Each variable's sub-quality index is called Q_i, Wi the weight unit of the specified variable is W_i, and there were 17 physicochemical characteristics (n = 17) that were expressed in mg/L. According to the Canadian Council of Ministers of the Environment, the calculated value of Qi is based on the surface water concentration (C_i) and the standard (S_i) for each surface water parameter's aquatic life value **(CCME 2007)**, as shown in Equation (2):

$$Q_i = \frac{C_i}{S_i} \times 100 \quad \text{……} \quad (2)$$

Equation (3) was used to calculate the W_i:

$$W_i = \frac{w_i}{\sum w_i} \quad \text{……} \quad (3)$$

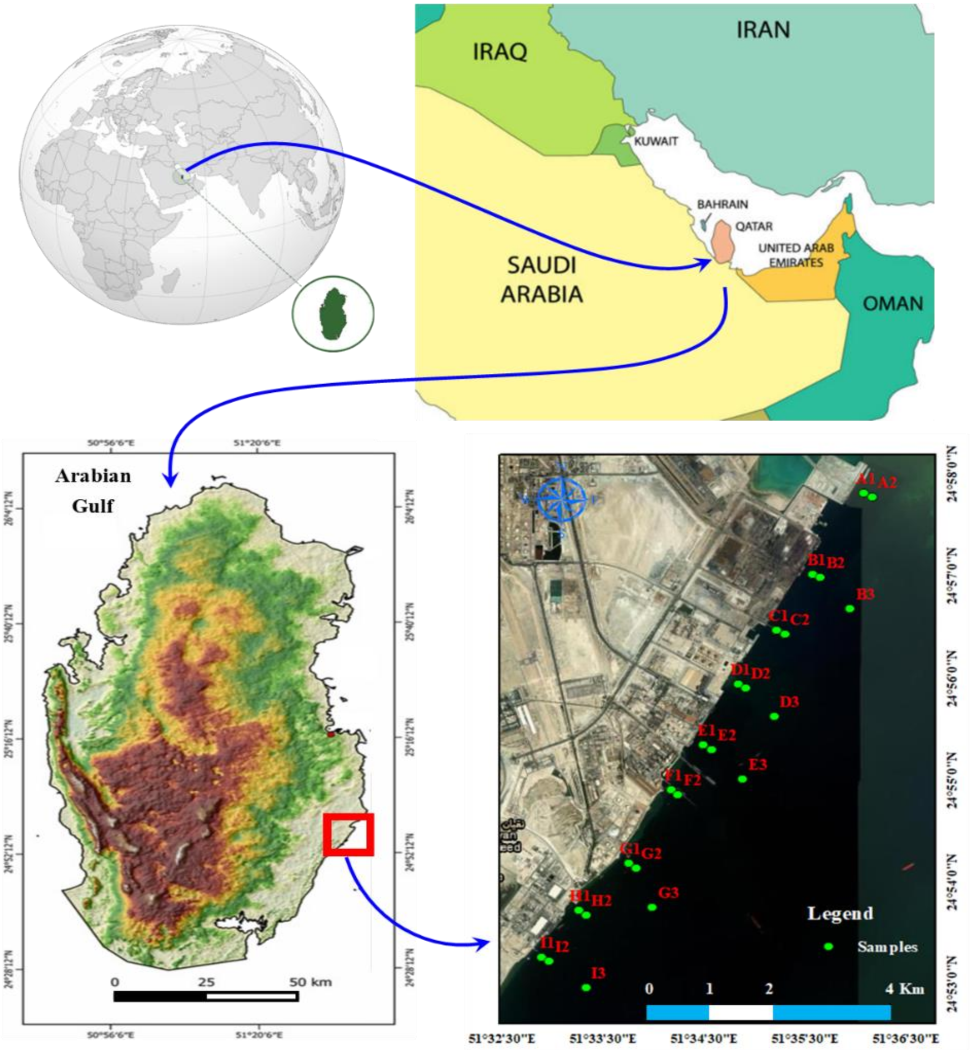


Fig. 3. Field Sampling Locations and Measuring Points.

The recommended standards are employed to estimate each parameter according to Equation (4):

$$w_i = \frac{K}{S_i} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

The proportionality constant is K.

Each surface water parameter (w_i) must be given a weight in order to compute the WAWQI. Additionally, the relative weight (W_i) and quality rating range (Q_i) must be determined. As a result, Table 3. allocated W_i values to certain physicochemical characteristics, and Equation (4) was used to calculate (w_i). Weighted values were assigned using the mathematical weight technique. Table 3 displays the weights (w_i) and arithmetic weights (W_i) for the water parameters, whereas Table 4. displays the assessment of quality values.

Results and Discussion

Seawater Quality

In addition to being a useful resource for learning about water chemistry and quality, physiochemical parameters are crucial in assessments of seawater quality. The physicochemical features of the trace elements and heavy metals in seawater samples collected from Mesaieed Seawater close to discharge locations during a two-year period are statistically described in Table 5. One of the factors influencing seawater quality, which regulates the biological, physical, and chemical activity in seawater, is temperature. It is also a crucial component of aquatic life.

Temperature in natural water bodies is subjected to great variation due to several climatic factors and geographical position. Among these factors; air temperature, latitude, sun altitude, season, wind, depth, confinement of the water body, waves, and gain or loss of heat, particularly in shallow water close to land. Seawater temperature detected during the study varied between min. of 26.15 ◦C to max. of 33.40 ◦C; with an annual average of 29.421 ◦C during summer and varied between min. of 16.13 ◦C to max. of 19.5 ◦C; with an annual average of 18.742 ◦C During winter across two years as shown in Table 5. Although, water in seawater lies in the optimal range foremost of the aquatic organisms, the steep temperature gradients, can have direct harmful effects on fish according to **(CCME 2007)** for aquatic life.

Hydrogen ion concentration (pH) is one of the most important parameters that, affects biota in aquatic environment. It plays an important role in many of the life processes where living organisms are very dependent and sensitive to pH variation. The Seawater pH values varied from 8.48 to 8.72, with a mean of 8.60 during summer and varied from 8.43 to 8.62, with a mean of 8.61 during winter across two years as shown in Table 5. which fell in the range of acceptable water for the aquatic life system according to the guidelines of the **(CCME 2007).**

Water salinity of the Gulf ranges from 37 psu at the Strait of Hormuz to about 43 psu in the central part of the Arabian Gulf **(El Gindy, 1992)**. Higher salinity values are observed in the shallow intertidal lagoons and at Salwa Bay where it frequently reaches a value of 70 psu or above **(Basson et. Al., 1977; Lindén et al., 1990)**. The high evaporation rate in the Arabian Gulf and its circulation pattern are the most important factors controlling salinity of the Qatari coast. Seawater salinity measured during the present research is summarized in Table 5. With a mean value of 45.60 across the summer and winter seasons over two years, the salinity values for the samples that were taken varied from 44.21 Psu to 45.81 Psu. The salinity values in the collected samples showed that the saltwater in Mesaieed will have high salinity values due to the effects of evaporation linked to extremely high solute dissolution and ongoing recharge from industrial wastewater discharge.

Table 3. Arithmetic rating method for trace elements parameters.

Trace Element (mg/L)	Si (mg/L) (CCME, 2007)	MAC_i	Unit Weight W_i	Sub Index Q_i	$W_i \times Q_i$
***Chromium (VI)**	0.0015	0.1	0.05432	10	0.543204128
Aluminium (Al)	0.1	0.039	0.00081	3.9	0.003177744
Barium (Ba)	0.05	0.22	0.00163	22	0.035851472
Cadmium (Cd)	0.001	1.1	0.08148	110	8.962868118
Chromium (Cr)	0.01	1.01	0.00815	101	0.822954254
Copper (Cu)	0.004	0.125	0.02037	12.5	0.254626935
Iron (Fe)	0.3	0.023333333	0.00027	2.333333333	0.000633738
Lead (Pb)	0.007	0.014285714	0.01164	1.428571429	0.016628698
Manganese (Mn)	0.05	0.022	0.00163	2.2	0.003585147
Mercury (Hg)	0.0001	1	0.81481	100	81.48061925
Nickel (Ni)	0.025	0.004	0.00326	0.4	0.00130369
			$\sum(W_i) = 1$		$\sum(W_i \times Q_i)$

*Cr (VI) Hexavalent Chromium.

Table 4. Assessment of AWQI for Seawater Quality.

AWQI	Water class
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
<100	Unsuitable

Table 5. Statistical description of Seawater quality parameters in MIC (2022-2023).

Seawater Quality Parameters 2022-2023																				
	T ◦C	**pH**	**Salinity**	**(C55H72MgN4O5)**	**NH3**	**NO3**	**NO2**	**TP**	**Cr (VI)**	**Al**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Zn**
1st Year – Summer Top 2022 (n= 23)																				
Min	27.81	8.50	44.21	0.01	0.02	0.04	0.016	0.01	0.00001	0.0029	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0001	0.01
Max	33.40	8.65	44.63	0.01	0.02	0.09	0.02	0.01	0.00001	0.0099	0.01	0.0003	0.0015	0.0032	0.00768	0.0001	0.0059	0.0001	0.0038	0.023
Mean	29.421	8.60	44.55	0.01	0.02	0.09	0.02	0.01	0.00001	0.0054	0.0100	0.0001	0.0005	0.0015	0.0053	0.0001	0.0019	0.0001	0.0015	0.0119
1st Year - Summer Bottom 2022 (n= 23)																				
Min	26.15	8.48	44.23	0.01	0.02	0.04	0.016	0.01	0.00001	0.0031	0.01	0.0001	0.0001	0.0003	0.005	0.0001	0.0001	0.0001	0.0003	0.01
Max	29.20	8.72	44.34	0.01	0.02	0.04	0.02	0.01	0.00001	0.125	0.23	0.0035	0.0116	0.0286	0.12098	0.0023	0.0381	0.0023	0.0335	0.266
Mean	27.152	8.55	44.29	0.01	0.02	0.04	0.01652	0.01	0.00001	0.0054	0.0100	0.0002	0.0005	0.0012	0.0053	0.0001	0.0017	0.0001	0.0015	0.0116
2nd Year - Winter Top 2023 (n= 23)																				
Min	18.25	8.43	45.15	0.011	0.021	0.042	0.015	0.011	0.00001	0.0034	0.011	0.0001	0.0001	0.0005	0.005	0.0001	0.0011	0.0001	0.0001	0.011
Max	19.50	8.45	45.71	0.014	0.023	0.223	0.025	0.012	0.00015	0.0118	0.014	0.0031	0.0101	0.002	0.061	0.0031	0.0031	0.0001	0.0021	0.011
Mean	18.742	8.52	45.60	0.0118	0.0213	0.0944	0.0192	0.0111	0.0001	0.006	0.011	0.001	0.001	0.001	0.012	0.001	0.001	0.000	0.000	0.011
2nd Year - Winter Bottom 2023 (n= 23)																				
Min	16.13	8.55	45.25	0.01000	0.02000	0.09130	0.01774	0.01000	0.00001	0.0034	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0001	0.01
Max	17.75	8.62	45.81	0.01000	0.02000	0.09130	0.01774	0.01000	0.00001	0.0117	0.01	0.0002	0.0014	0.0011	0.061	0.0001	0.0001	0.0001	0.0006	0.01
Mean	17.235	8.63	45.33	0.01000	0.02000	0.09130	0.01774	0.01000	0.00001	0.0060	0.0100	0.0001	0.0003	0.0007	0.0116	0.0001	0.0001	0.0001	0.0001	0.0100

*All water quality parameters are expressed in mg/L except temperature (T ◦C), pH, and Salinity (Psu)

Trace elements and Heavy Metals Impact to Seawater Quality

On the other hand, the research focus on some trace element concentrations of Chlorophyll 'a', NH3, NO3, NO2, TP, (Cr-VI), AL, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, and Zn as shown in the Table 5. showed mean values of Seawater quality parameters in MIC over two years. 0.012, 0.021, 0.223, 0.017, 0.011, 0.00015, 0.0039, 0.011,0.0011, 0.0101, 0.0005, 0.007, 0.0001, 0.0011, 0.0001, 0.0001, and 0.011 mg/L, respectively as the following trend: NO3 > NH3 > NO2 > Chlorophyll 'a'(C55H72MgN4O5) > TP > Ba > Zn > Cr > Iron > Fe > Al > Cd > Mn > Cu > Cr-VI > Pb > Hg > Ni To the best of our knowledge, there are two natural (rock weathering and soil leaching) and man-made (treated industrial wastewater discharge streams) sources of trace elements or heavy metals in seawater. Indicating that the seawater was moderately contaminated by the aforementioned trace elements, at levels that were within the bounds of the proposed permissible limits for the protection of aquatic life, the concentrations of these elements varied considerably amongst the water samples that were collected (CCME 2007).

Weighted Arithmetic Water Quality Index (WAWQI)

Seawater quality indices (WAWQI) during the summer (Top-Bottom) and winter (Top-Bottom) of 2023–2023 were statistically described in Table 6. The results showed that most of seawater samples were inappropriate water categories and not advised for the marine environment. The WAWQI values ranged from 82.54332 to 85.39405, with a mean value of 83.44755 during the summer and from 82.63651 to 108.3168, with a mean value of 88.33134. Thus, one of the most difficult steps to safeguard the marine environment in Mesaieed Industrial City Seawater is to improve pollution control.

The majority of the degradation in seawater quality was found close to the discharge and stream points network in Mesaieed Industrial City seawater at the end of drain discharging, according to the spatial distribution maps of AWQI values of the sea water in the research area Figs. 4, 5, 6, and 7. The flow of industrial effluent into the seawater surrounding Mesaieed Industrial City (MIC) might be the cause of this.

Conclusion

In this study conducted in Mesaieed Industrial City (MIC), Qatar. Various parameters of seawater quality temperature (°C), pH, salinity (psu), in addition to the heavy metals parameters have the following trend: NO3 > NH3 > NO2 > Chlorophyll 'a' > TP > Ba > Zn > Cr > Fe > Al > Cd > Mn > Cu > Cr-VI > Pb > Hg > Ni were measured respectively. an investigation was conducted on the physicochemical properties of seawater samples in order to evaluate its appropriateness for aquatic life use. Brine discharge and treated industrial wastewater effluents were regarded as the main causes of trace element pollution in Mesaieed Seawater, according to the AWQI and multivariate statistical analysis. Furthermore, higher remediation of the deterioration of seawater quality in the examined gulf region would result from the employment of efficient and more sophisticated wastewater treatment techniques before discharge into the sea. The analysis revealed that in

Table 6. AWQI Statistical Description in Seawater (2022-2023).

SAMPLE NO.	**SUMMER TOP**	**SUMMER BOTTOM**	**WINTER TOP**	**WINTER BOTTOM**
	AWQI	**AWQI**	**AWQI**	**AWQI**
A1	83.05155819	82.64258641	92.29829204	82.85760627
B1	83.1531874	82.85836509	100.5116495	82.89023896
C1	82.79132705	83.39507223	108.3167592	83.5020842
D1	82.89035319	82.79455003	83.46714673	82.84440778
E1	82.9520733	82.54331855	83.11434841	82.77353798
F1	83.14803063	84.1160534	83.5206047	82.73887518
G1	84.23232249	83.89455393	83.68708936	82.82917919
H1	84.66315466	85.3940465	91.49142106	82.6428342
I1	84.46605765	84.14271194	83.78227098	83.441534
A2	82.74628587	82.64113607	83.00176818	82.739287
B2	82.90251994	82.80890126	84.18955838	83.75235268
C2	82.94409642	82.74088738	91.26884464	82.70373572
D2	82.64347273	82.6492741	91.13837619	82.65624828
E2	82.99977165	82.69487751	91.2407139	82.67801236
F2	84.16737939	84.43537038	83.50893222	82.64549605
G2	84.36478707	84.22756859	83.75945048	82.81551227
H2	84.4919185	84.62406973	83.33550796	82.63650967
I2	84.42336477	84.04812904	83.34914564	82.64502545
B3	82.78855387	82.64186124	91.44716072	82.85522484
D3	83.25866845	82.74137082	91.23319054	82.63908806
E3	83.93404442	83.75854407	91.58095746	82.9062733
G3	85.82463695	84.62955507	91.28733444	82.69316038
I3	83.16406497	83.92574524	92.17725244	82.63640787
AWQI				
Min	82.64347273	82.54331855	83.00176818	82.63650967
Max	84.66315466	85.3940465	108.3167592	83.75235268
Mean	83.44754683	83.44725548	88.33133729	82.89102658

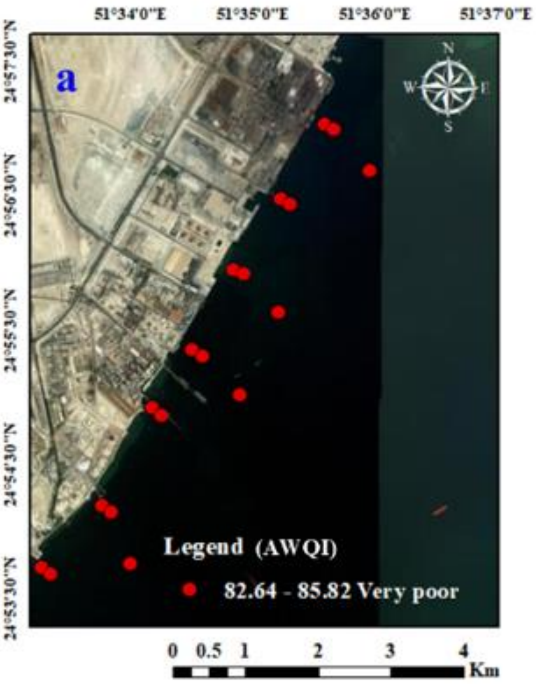


Fig. 4. AWQI Spatial Distribution Maps - Summer Top Samples

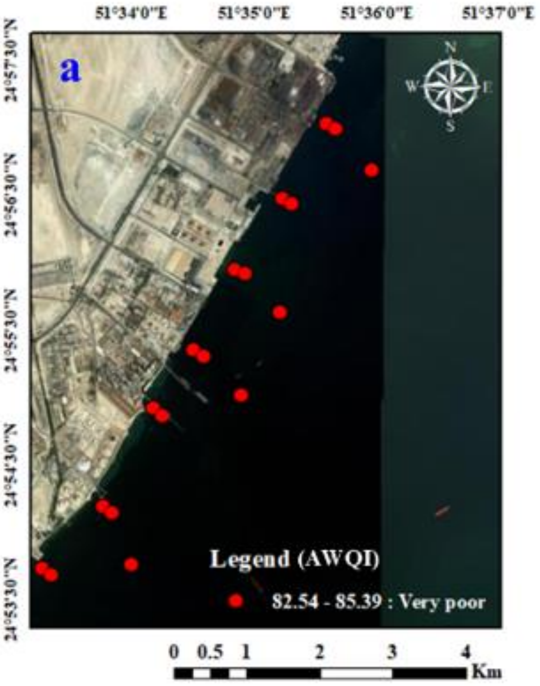


Fig. 5. AWQI Spatial Distribution Maps- Summer Bottom Samples

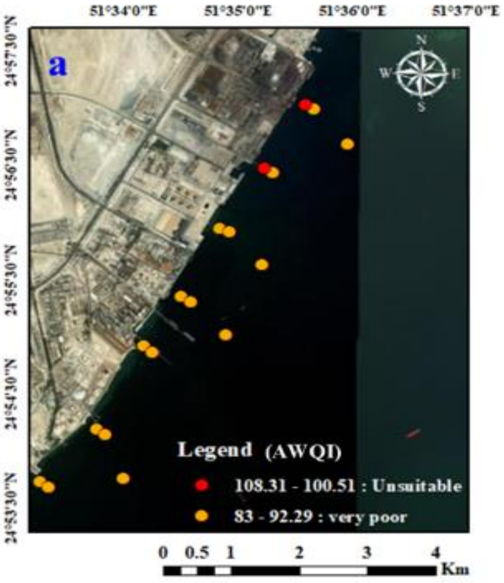


Fig. 6. AWQI Spatial Distribution Maps -Winter Top Samples

Fig. 7. AWQI Spatial Distribution Maps- Winter Bottom Samples

the study area, the seawater had a saline nature, with elevated levels of certain trace elements, notably some parameters significantly affected the seawater quality, while minor parameters had a moderate effect, and one parameter had a slight effect. Therefore, implementing effective wastewater treatment procedures in advance of discharging into the seawater is crucial to mitigating the deteriorating of the quality of seawater in the investigated area. The research also revealed a deterioration in the Seawater quality of the gulf region in recent years due to major drainage and unplanned development, leading to adverse effects on the marine life. Water quality varied across different locations, with areas near estuaries experiencing a decrease in quality due to the influx of large volumes of wastewater. Industries drainage streams were identified as the most severely affected areas in the Seawater.

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