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Environmental Impact Assessment Study Associated with Heavy Metals in Aquatic Life at Arabian Gulf Region

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Abstract

The rapid, unplanned growth of petroleum industries has degraded seawater quality around Mesaieed Industrial City (MIC), impacting marine ecosystems and aquatic life. This study aims to refine assessments of MIC seawater quality, identifying key environmental parameters affecting its health. Seawater samples were collected from 23 locations during 2022-2023 in both summer and winter, with analyses at surface and bottom layers to capture seasonal changes. Seventeen 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 examined. Results showed significant contamination, with NO3, NH3, NO2, and Chlorophyll 'a' as primary contaminants, while others showed moderate impacts on water quality and aquatic life. To better interpret contamination sources and patterns, multivariate methods such as cluster analysis (CA) and principal component analysis (PCA) were employed, revealing distinct pollution clusters and sources affecting MIC seawater. A key finding was the concerning rise in salinity, primarily from brine and treated industrial wastewater (TIW) discharges, which intensify seawater quality deterioration and hasten ecological damage. These results highlight the critical need for more advanced wastewater treatment prior to discharge, as current practices elevate salinity and contamination to levels posing significant ecological risks. Immediate measures are essential to reduce industrial drainage impacts and protect MIC's marine environment, maintaining seawater quality necessary for aquatic life and ecological health.

Keywords: Seawater, Industrial Treated Wastewater, Petroleum Industries, aquatic life, heavy metals.

Introduction

Unchecked urbanisation and industrialisation have drastically altered the natural environment. The most productive, diverse, and dynamic ecosystems on Earth are found in seawater. The biological community, physiochemical components, and their interactions comprise the aquatic ecosystem. Changes don't happen in a state of inactivity; there is a complicated interaction between biological and physical processes in the aquatic environment **(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; El-Zeiny et al., 2019).** 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 nearby the majority of the petroleum industries there, is one of Qatar's most significant sea-aquatic ecosystems. It also acts as the main reservoir for the outflow of industrially treated wastewater in Mesaieed. 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.

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., 2012), (Smith et al., 2021; Ustaoğlu et al., 2021).**

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'($C_{55}H_{72}MgN_4O_5$), NH_3, NO_3, 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; Environ. Monit. Assess., 2019).** Heavy metals such as Zn, while vital for living organisms, become toxic in excessive amounts **(Ecol. Modell., 2011).**

Practicality, speed, and cost-effectiveness compared to conventional laboratory analysis methods **(Gad, M.et al.2021), (Elsayed and Elhoweity et al., 2017; Wong and Khallel et al., 2022)** In addition to ML models, decision-makers can employ multivariate analysis methods such as Cluster Analysis (CA) and Principal Component Analysis (PCA), which are valuable tools for data reduction and for interpreting chemical information, enabling the exploration of seawater chemistry variations **(Rodionova et al., 2021**). These techniques provide valuable insights into the underlying patterns and control mechanisms of water quality variations.

By integrating these multivariate analysis tools with ML modelling, a comprehensive framework can be established to predict seawater quality for different purposes, empowering effective decision-making in water management. Therefore, The Objectives of this work to evaluate the contamination risks of 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.

Fig. 1. Location of the Study Area.

Sampling and Analysis

Seawater samples were collected from 23 locations points in 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 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.

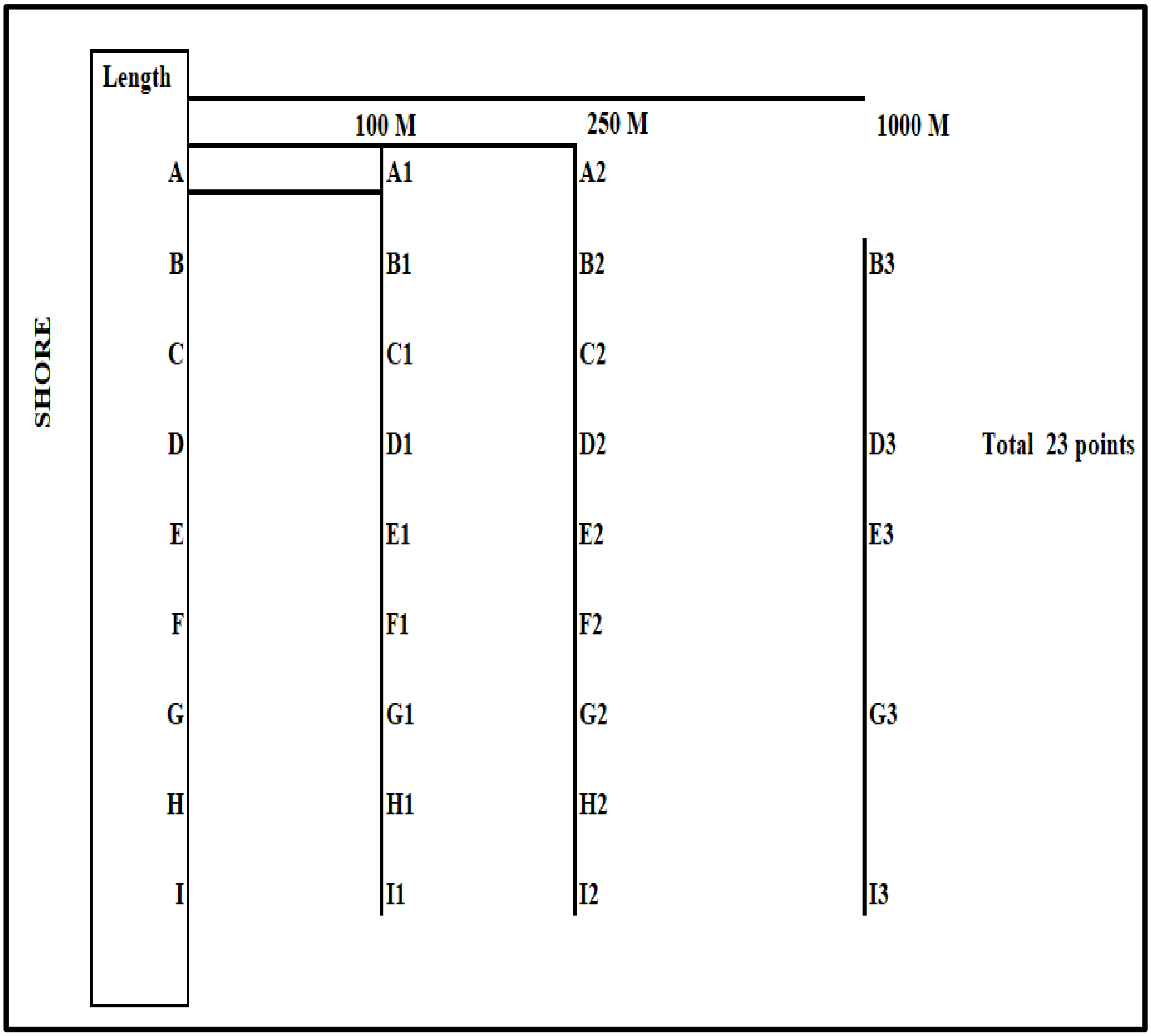

Fig. 2. Sampling Points.

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	√	√	√	√	√	√

The samples were collected following standard protocols as outlined in the American Public Health Association (APHA Guidelines, 2017). The location of the collected samples was determined by UTM coordinates using handheld MAGELLAN GPS 315. as shown in Fig. 3 of Field Sampling Locations and Measuring Points.

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 inductively coupled plasma mass spectrometer (ICAP TQ ICP-MS Thermo Fisher Scientific Inc., Waltham, MA, USA) Samples were then transferred under chain of custody documentation to an approved laboratory (EXOVA L.L.C. Doha-Qatar) for analysis.

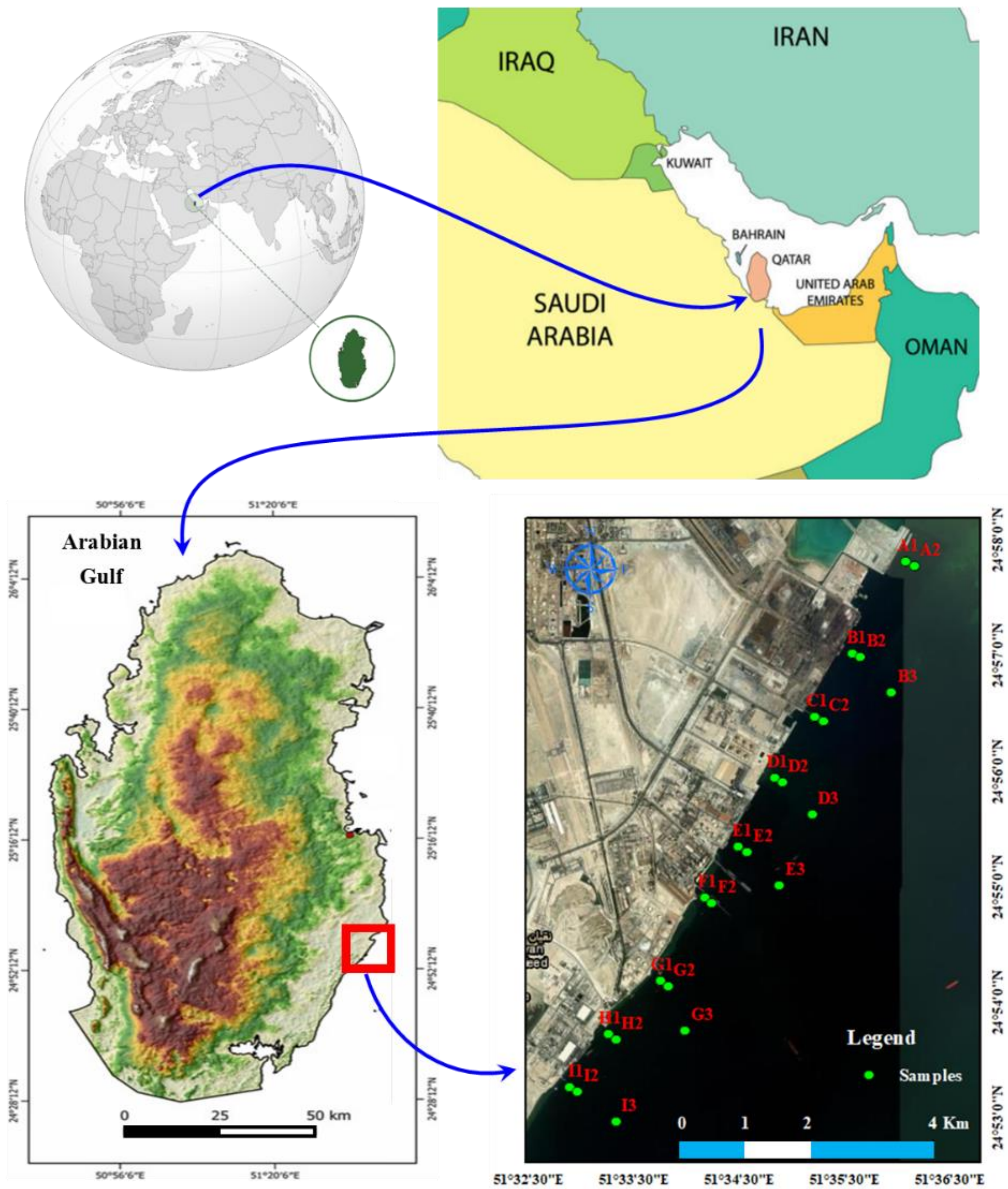

Fig. 3. Field Sampling Locations and Measuring Points.

Multivariate Statistics

Cluster Analysis (CA)

Hierarchical cluster analysis (CA) is a dependable data extraction technique for finding patterns within homogeneous groups or clusters of instances (variables) **(Ghodbane et al., 2022)**. The basic idea behind this approach is to join successively comparable groupings of points to construct a binary data tree. High levels of intra- and inter-cluster heterogeneity should then be present in the growing point clusters **(Athamena et al., 2023)**. Several techniques were used to find grouping across the sampling sites, detect geographic similarity, and form and combine consistent groups of water samples into meaningful clusters. Additionally, Ward's linkage criteria are used for the clustering, and the results are shown as a 2-D diagram called a dendrogram.

Principal Component Analysis (PCA)

In exploratory data analysis, PCA is a frequently used approach that aims to reduce the number of dimensions in high-dimensional data. This is achieved by breaking down a collection of connected variables into a smaller set of unrelated variables known as principle components (PCs). Eigenvectors, which are independent variables that represent the weightings and are orthogonal to one another, are used to combine the original variables to create the PCs. The majority of the variation in the dataset is captured by the first PC, with the remainder being explained by successive PCs. Each of the sequentially ordered PCs contributes less to the total variability than the one before it **(Salem et al., 2023).**

Results and Discussion

Sea water 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 over a two-year period are statistically described in **Table 2**. One of the factors influencing seawater quality, which regulates the biological, physical, and chemical activity in saltwater, 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 2** Even if the water in seawater is within the ideal range for aquatic life, fish may suffer direct injury from the sharp temperature changes, according to (**CCME, 2007)**.

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 2** 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)** and **(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 2** The salinity values for the collected samples ranged between 44.21 Psu and 45.81 Psu, with a mean value of 45.60 during summer and winter across two years, regarding to the effect of evaporation associated with very high solute dissolution and continuous recharging from industrial wastewater discharge in Mesieed seawater, the salinity values in the obtained samples revealed that the seawater in Mesaieed will be on high salinity values.

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 Table 2 summarize the statistical description of seawater quality parameters in MIC over two years 2022-2023 and the Water Quality Parameters Raw Data in seawater as shown in Tables 3,4,5, and 6.

The mean values of Seawater quality parameters in Mesaieed Industrial City (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' > TP > Ba > Zn > Cr > Iron > Fe > Al > Cd > Mn > Cu > Cr-VI > Pb > Hg > Ni. to the best of our knowledge, trace elements or heavy metals in seawater come from two sources, natural (rock weathering and soil leaching) and anthropogenic (Treated Industrial Wastewater discharge streams). The trace elements concentrations in the collected water samples differed significantly between samples, indicating that the seawater was moderately contaminated by the above trace elements, at levels that were within the borderline of the proposed permissible limits for the protection of aquatic life according to the (CCME 2007).

Multivariate statistical analysis
Cluster analysis (CA)

Cluster analysis or clustering is the most basic quantitative method for estimating similarities. After it was carried out the hierarchical cluster analysis, the process was represented on a diagram known as a dendrogram **(Athamna et al., 2023)**. The diagrams illustrate which clusters have been joined at each stage of the analysis and the distance between clusters at the time of joining. Cluster analysis grouped the studied sampling sections into clusters on the basis of similarities within a group and dissimilarities between different groups **Fig. 4.** R-mode has been employed to perform and create CA. These methods have been used for the creation and merging of consistent sets of seawater samples into meaningful clusters, and for assessing spatial similarities and location clustering within the sampling stations **(Gad et al., 2016)**. Ward's linkage criterion was utilized for the clustering

Table 2. Statistical description of Seawater quality parameters in MIC (2022-2023).

Water Quality Parameters 2022-2023																				
	T ◦C	**pH**	**Salinity**	**($C_{55}H_{72}MgN_4O_5$)**	**NH_3**	**NO_3**	**NO_2**	**TP**	**Cr (VI)**	**Al**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Zn**
First 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
First 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
Second 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
Second 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)

Table 3. Water Quality Parameters Raw Data in Seawater - Summer Top Results.

PARAMETER	Chlorophyll 'a' **($C_{55}H_{72}MgN_4O_5$)**	**Nitrogen (NH_3)**	**Nitrate (NO_3)**	**Nitrite (NO_2)**	**Total Phosphorus (TP)**	**Chromium (Cr-VI)**	**Aluminium (Al)**	**Barium (Ba)**	**Cadmium (Cd)**	**Chromium (Cr)**	**Copper (Cu)**	**Iron (Fe)**	**Lead (Pb)**	**Manganese (Mn)**	**Mercury (Hg)**	**Nickel (Ni)**	**Zinc (Zn)**
UNITS	**mg/m3**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
***LIMITS**	**0.01**	**1**	**2.93**	**0.06**	**0.05**	**0.0015**	**0.1**	**0.05**	**0.001**	**0.01**	**0.004**	**0.3**	**0.007**	**0.05**	**0.0001**	**0.025**	**0.05**
A1	0.01	0.02	0.09	0.02	0.01	0.00001	0.0052	0.01	0.0001	0.0001	0.0013	0.005	0.0001	0.0001	0.0001	0.0003	0.01
B1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0067	0.01	0.0001	0.0001	0.0015	0.005	0.0001	0.0008	0.0001	0.0008	0.01
C1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0043	0.01	0.0001	0.0001	0.0008	0.005	0.0001	0.0001	0.0001	0.0004	0.01
D1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0042	0.01	0.0001	0.0001	0.001	0.005	0.0001	0.0004	0.0001	0.0002	0.01
E1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0099	0.01	0.0001	0.0001	0.0011	0.005	0.0001	0.0001	0.0001	0.0008	0.01
F1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0044	0.01	0.0001	0.0005	0.0014	0.005	0.0001	0.0022	0.0001	0.0016	0.01
G1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0077	0.01	0.0002	0.0012	0.0018	0.005	0.0001	0.0036	0.0001	0.0019	0.013
H1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0073	0.01	0.0002	0.0015	0.0025	0.005	0.0001	0.0059	0.0001	0.0038	0.02
I1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0045	0.01	0.0002	0.0013	0.0022	0.00577	0.0001	0.0053	0.0001	0.0023	0.018
A2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0061	0.01	0.0001	0.0001	0.0007	0.005	0.0001	0.0001	0.0001	0.0007	0.01
B2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0069	0.01	0.0001	0.0001	0.001	0.005	0.0001	0.0007	0.0001	0.0009	0.01
C2	0.01	0.02	0.04	0.016	0.01	0.00001	0.004	0.01	0.0001	0.0001	0.0011	0.005	0.0001	0.0003	0.0001	0.0005	0.01
D2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0035	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0007	0.01
E2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0047	0.01	0.0001	0.0001	0.0012	0.00768	0.0001	0.0001	0.0001	0.0009	0.01
F2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0039	0.01	0.0002	0.0006	0.0018	0.005	0.0001	0.0028	0.0001	0.0018	0.01
G2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0029	0.01	0.0002	0.0004	0.0022	0.005	0.0001	0.0028	0.0001	0.0028	0.01
H2	0.01	0.02	0.04	0.016	0.01	0.00001	0.004	0.01	0.0002	0.0015	0.0022	0.00753	0.0001	0.0054	0.0001	0.0038	0.015
I2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0049	0.01	0.0002	0.0015	0.0021	0.005	0.0001	0.0036	0.0001	0.0028	0.015
B3	0.01	0.02	0.09	0.016	0.01	0.00001	0.0056	0.01	0.0001	0.0001	0.0008	0.005	0.0001	0.0001	0.0001	0.0001	0.01
D3	0.01	0.02	0.04	0.02	0.01	0.00001	0.0059	0.01	0.0001	0.0001	0.0017	0.005	0.0001	0.0001	0.0001	0.0007	0.01
E3	0.01	0.02	0.04	0.02	0.01	0.00001	0.006	0.01	0.0002	0.0002	0.0014	0.005	0.0001	0.0004	0.0001	0.0016	0.01
G3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0057	0.01	0.0003	0.0015	0.0032	0.005	0.0001	0.0051	0.0001	0.0036	0.023
I3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0051	0.01	0.0001	0.0006	0.0014	0.005	0.0001	0.0025	0.0001	0.0021	0.01

Table 4. Water Quality Parameters Raw Data in Seawater - Summer Bottom Results.

PARAMETER	Chlorophyll ‘a' **(C55H72MgN4O5)**	**Nitrogen (NH3)**	**Nitrate (NO3)**	**Nitrite (NO2)**	**Total Phosphorus (TP)**	**Chromium (Cr-VI)**	**Aluminium (Al)**	**Barium (Ba)**	**Cadmium (Cd)**	**Chromium (Cr)**	**Copper (Cu)**	**Iron (Fe)**	**Lead (Pb)**	**Manganese (Mn)**	**Mercury (Hg)**	**Nickel (Ni)**	**Zinc (Zn)**
UNITS	**mg/m3**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
***LIMITS**	**0.01**	**1**	**2.93**	**0.06**	**0.05**	**0.0015**	**0.1**	**0.05**	**0.001**	**0.01**	**0.004**	**0.3**	**0.007**	**0.05**	**0.0001**	**0.025**	**0.05**
A1	0.01	0.02	0.04	0.016	0.01	0.00001	0.004	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0006	0.01
B1	0.01	0.02	0.04	0.016	0.01	0.00001	0.007	0.01	0.0001	0.0002	0.0009	0.005	0.0001	0.0009	0.0001	0.0007	0.01
C1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0052	0.01	0.0001	0.0001	0.002	0.005	0.0001	0.0001	0.0001	0.0003	0.01
D1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0051	0.01	0.0001	0.0001	0.0008	0.005	0.0001	0.0001	0.0001	0.0006	0.01
E1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0054	0.01	0.0001	0.0001	0.0003	0.005	0.0001	0.0002	0.0001	0.0006	0.01
F1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0039	0.01	0.0002	0.0007	0.0017	0.005	0.0001	0.0024	0.0001	0.0012	0.01
G1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0047	0.01	0.0002	0.0009	0.0012	0.005	0.0001	0.0034	0.0001	0.002	0.01
H1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0076	0.01	0.0003	0.0009	0.0025	0.005	0.0001	0.0038	0.0001	0.003	0.017
I1	0.01	0.02	0.04	0.016	0.01	0.00001	0.005	0.01	0.0002	0.0011	0.0016	0.00577	0.0001	0.004	0.0001	0.0032	0.014
A2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0038	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0005	0.01
B2	0.01	0.02	0.04	0.02	0.01	0.00001	0.0062	0.01	0.0001	0.0001	0.0008	0.005	0.0001	0.0007	0.0001	0.0008	0.01
C2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0058	0.01	0.0001	0.0001	0.0007	0.005	0.0001	0.0001	0.0001	0.0003	0.01
D2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0079	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0004	0.0001	0.0008	0.01
E2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0045	0.01	0.0001	0.0001	0.0006	0.00768	0.0001	0.0001	0.0001	0.0007	0.01
F2	0.01	0.02	0.04	0.016	0.01	0.00001	0.004	0.01	0.0002	0.0006	0.0023	0.005	0.0001	0.0026	0.0001	0.0021	0.014
G2	0.01	0.02	0.04	0.016	0.01	0.00001	0.005	0.01	0.0002	0.0009	0.0018	0.005	0.0001	0.0041	0.0001	0.0032	0.014
H2	0.01	0.02	0.04	0.02	0.01	0.00001	0.0159	0.01	0.0002	0.0015	0.0024	0.00753	0.0001	0.0044	0.0001	0.0038	0.02
I2	0.01	0.02	0.04	0.016	0.01	0.00001	0.0034	0.01	0.0002	0.0008	0.0015	0.005	0.0001	0.0032	0.0001	0.0022	0.013
B3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0031	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0006	0.01
D3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0044	0.01	0.0001	0.0001	0.0007	0.005	0.0001	0.0002	0.0001	0.0004	0.01
E3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0041	0.01	0.0002	0.0006	0.001	0.005	0.0001	0.0013	0.0001	0.0017	0.01
G3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0044	0.01	0.0002	0.0016	0.0025	0.005	0.0001	0.0041	0.0001	0.0027	0.014
I3	0.01	0.02	0.04	0.02	0.01	0.00001	0.0046	0.01	0.0002	0.0007	0.0013	0.005	0.0001	0.0017	0.0001	0.0015	0.01

Table 5. Water Quality Parameters Raw Data in Seawater -Winter Top Results.

PARAMETER	Chlorophyll 'a' ($C_{55}H_{72}MgN_4O_5$)	Nitrogen (NH_3)	Nitrate (NO_3)	Nitrite (NO_2)	Total Phosphorus (TP)	Chromium (Cr-VI)	Aluminium (Al)	Barium (Ba)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Zinc (Zn)
UNITS	**mg/m3**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
***LIMITS**	**0.01**	**1**	**2.93**	**0.06**	**0.05**	**0.0015**	**0.1**	**0.05**	**0.001**	**0.01**	**0.004**	**0.3**	**0.007**	**0.05**	**0.0001**	**0.025**	**0.05**
A1	0.011	0.021	0.091	0.024	0.011	0.00011	0.0074	0.011	0.0011	0.0011	0.0019	0.011	0.0021	0.0021	0.0001	0.0012	0.011
B1	0.011	0.021	0.092	0.018	0.012	0.00011	0.0078	0.012	0.0021	0.0021	0.002	0.015	0.0022	0.0031	0.0001	0.0021	0.011
C1	0.012	0.022	0.044	0.021	0.012	0.00012	0.0053	0.014	0.0031	0.0031	0.0008	0.0052	0.0031	0.0021	0.0001	0.0021	0.011
D1	0.011	0.021	0.043	0.019	0.011	0.00011	0.0067	0.011	0.0001	0.0014	0.0007	0.012	0.0011	0.0011	0.0001	0.0001	0.011
E1	0.012	0.021	0.045	0.017	0.011	0.00002	0.0044	0.011	0.0001	0.0001	0.0007	0.012	0.0011	0.0011	0.0001	0.0001	0.011
F1	0.013	0.021	0.092	0.018	0.011	0.00011	0.0061	0.011	0.0001	0.0001	0.0007	0.009	0.0011	0.0011	0.0001	0.0001	0.011
G1	0.014	0.021	0.044	0.016	0.011	0.00011	0.0055	0.011	0.0001	0.0006	0.0008	0.012	0.0011	0.0011	0.0001	0.0001	0.011
H1	0.013	0.021	0.183	0.015	0.011	0.00011	0.0118	0.011	0.0011	0.0003	0.0005	0.009	0.0011	0.0011	0.0001	0.0001	0.011
I1	0.012	0.022	0.184	0.017	0.011	0.00001	0.0034	0.011	0.0002	0.0001	0.0005	0.005	0.0011	0.0011	0.0001	0.0001	0.011
A2	0.011	0.022	0.094	0.018	0.011	0.00001	0.0065	0.011	0.0001	0.0001	0.0007	0.01	0.0011	0.0011	0.0001	0.0001	0.011
B2	0.011	0.021	0.133	0.019	0.011	0.00001	0.0062	0.011	0.0002	0.0002	0.0011	0.006	0.0021	0.0011	0.0001	0.0006	0.011
C2	0.012	0.022	0.092	0.018	0.011	0.00001	0.0053	0.011	0.0011	0.0003	0.0006	0.008	0.0021	0.0011	0.0001	0.0001	0.011
D2	0.011	0.021	0.043	0.024	0.011	0.00001	0.0095	0.011	0.0011	0.0001	0.0005	0.006	0.0021	0.0011	0.0001	0.0001	0.011
E2	0.012	0.021	0.042	0.017	0.011	0.00002	0.0054	0.011	0.0011	0.0001	0.0005	0.061	0.0021	0.0011	0.0001	0.0001	0.011
F2	0.012	0.021	0.043	0.021	0.011	0.00011	0.0047	0.011	0.0001	0.0001	0.0005	0.005	0.0021	0.0011	0.0001	0.0001	0.011
G2	0.013	0.022	0.133	0.017	0.011	0.00011	0.0105	0.011	0.0001	0.001	0.0007	0.015	0.0021	0.0011	0.0001	0.0001	0.011
H2	0.012	0.021	0.093	0.017	0.011	0.00011	0.0046	0.011	0.0001	0.0001	0.0005	0.005	0.0011	0.0011	0.0001	0.0001	0.011
I2	0.011	0.021	0.134	0.023	0.011	0.00011	0.0047	0.011	0.0001	0.0011	0.0005	0.006	0.0011	0.0011	0.0001	0.0001	0.011
B3	0.011	0.021	0.093	0.024	0.011	0.00011	0.0065	0.011	0.0011	0.0011	0.0009	0.005	0.0001	0.0011	0.0001	0.0001	0.011
D3	0.011	0.022	0.094	0.018	0.011	0.00011	0.0046	0.011	0.0011	0.0011	0.0005	0.032	0.0001	0.0011	0.0001	0.0001	0.011
E3	0.012	0.023	0.093	0.025	0.011	0.00011	0.0067	0.011	0.0011	0.0011	0.001	0.01	0.0001	0.0011	0.0001	0.0001	0.011
G3	0.011	0.021	0.043	0.018	0.011	0.00011	0.0042	0.011	0.0011	0.0018	0.0005	0.011	0.0001	0.0011	0.0001	0.0001	0.011
I3	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	0.011

Table 6. Water Quality Parameters Raw Data in Seawater-Winter Bottom Results.

PARAMETER	Chlorophyll 'a' (C55H72MgN4O5)	Nitrogen (NH3)	Nitrate (NO3)	Nitrite (NO2)	Total Phosphorus (TP)	Chromium (Cr-VI)	Aluminium (Al)	Barium (Ba)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Zinc (Zn)
UNITS	**mg/m3**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
***LIMITS**	**0.01**	**1**	**2.93**	**0.06**	**0.05**	**0.0015**	**0.1**	**0.05**	**0.001**	**0.01**	**0.004**	**0.3**	**0.007**	**0.05**	**0.0001**	**0.025**	**0.05**
A1	0.01	0.02	0.09	0.023	0.01	0.00001	0.0072	0.01	0.0001	0.0001	0.0009	0.01	0.0001	0.0001	0.0001	0.0002	0.01
B1	0.01	0.02	0.09	0.016	0.01	0.00001	0.0068	0.01	0.0001	0.0001	0.001	0.005	0.0001	0.0001	0.0001	0.0001	0.01
C1	0.01	0.02	0.04	0.02	0.01	0.00001	0.0051	0.01	0.0002	0.0001	0.0006	0.005	0.0001	0.0001	0.0001	0.0001	0.01
D1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0067	0.01	0.0001	0.0014	0.0007	0.012	0.0001	0.0001	0.0001	0.0001	0.01
E1	0.01	0.02	0.04	0.016	0.01	0.00002	0.0043	0.01	0.0001	0.0001	0.0007	0.012	0.0001	0.0001	0.0001	0.0001	0.01
F1	0.01	0.02	0.09	0.016	0.01	0.00001	0.006	0.01	0.0001	0.0001	0.0007	0.009	0.0001	0.0001	0.0001	0.0001	0.01
G1	0.01	0.02	0.04	0.016	0.01	0.00001	0.0053	0.01	0.0001	0.0006	0.0008	0.012	0.0001	0.0001	0.0001	0.0001	0.01
H1	0.01	0.02	0.18	0.016	0.01	0.00001	0.0117	0.01	0.0001	0.0001	0.0005	0.009	0.0001	0.0001	0.0001	0.0001	0.01
I1	0.01	0.02	0.18	0.016	0.01	0.00001	0.0034	0.01	0.0002	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0001	0.01
A2	0.01	0.02	0.09	0.016	0.01	0.00001	0.0064	0.01	0.0001	0.0001	0.0007	0.01	0.0001	0.0001	0.0001	0.0001	0.01
B2	0.01	0.02	0.13	0.016	0.01	0.00001	0.0061	0.01	0.0002	0.0001	0.0011	0.006	0.0001	0.0001	0.0001	0.0006	0.01
C2	0.01	0.02	0.09	0.016	0.01	0.00001	0.005	0.01	0.0001	0.0003	0.0006	0.008	0.0001	0.0001	0.0001	0.0001	0.01
D2	0.01	0.02	0.04	0.023	0.01	0.00001	0.0094	0.01	0.0001	0.0001	0.0005	0.006	0.0001	0.0001	0.0001	0.0001	0.01
E2	0.01	0.02	0.04	0.016	0.01	0.00002	0.0053	0.01	0.0001	0.0001	0.0005	0.061	0.0001	0.0001	0.0001	0.0001	0.01
F2	0.01	0.02	0.04	0.02	0.01	0.00001	0.0045	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0001	0.01
G2	0.01	0.02	0.13	0.016	0.01	0.00001	0.0104	0.01	0.0001	0.001	0.0007	0.015	0.0001	0.0001	0.0001	0.0001	0.01
H2	0.01	0.02	0.09	0.016	0.01	0.00001	0.0044	0.01	0.0001	0.0001	0.0005	0.005	0.0001	0.0001	0.0001	0.0001	0.01
I2	0.01	0.02	0.13	0.02	0.01	0.00001	0.0037	0.01	0.0001	0.0001	0.0005	0.006	0.0001	0.0001	0.0001	0.0001	0.01
B3	0.01	0.02	0.09	0.023	0.01	0.00001	0.0064	0.01	0.0001	0.0001	0.0009	0.005	0.0001	0.0001	0.0001	0.0001	0.01
D3	0.01	0.02	0.09	0.016	0.01	0.00001	0.0046	0.01	0.0001	0.0001	0.0005	0.032	0.0001	0.0001	0.0001	0.0001	0.01
E3	0.01	0.02	0.09	0.023	0.01	0.00001	0.0067	0.01	0.0001	0.0001	0.001	0.01	0.0001	0.0001	0.0001	0.0001	0.01
G3	0.01	0.02	0.04	0.016	0.01	0.00001	0.0041	0.01	0.0001	0.0008	0.0005	0.011	0.0001	0.0001	0.0001	0.0001	0.01
I3	0.01	0.02	0.22	0.016	0.01	0.00001	0.0039	0.01	0.0001	0.0001	0.0005	0.007	0.0001	0.0001	0.0001	0.0001	0.01

*Canadian Council of Ministers of the Environment (CCME-2007).

process, and the results are presented in the form of a dendrogram and a 2-D diagram **(Gaagai et al., 2017)**. The R-mode cluster analysis executed for the chemicals elements on GW samples produces three clusters Fig. 4.

A total of seventeen variables were produced dendrograms with two groups controlled by NO_3. Cluster 1 consists in majority by the nutriments elements as NO_2, NH_3, TP, and some others heavy metals as Fe, Al, Zn, Ba, Chl. However, the second cluster identified by the Mn, Ni, Cu, Cr, Pb, Cd, Hg, Cr-IV. Despite the existence of hazardous substances and variations in their quantities being identical, the dendrogram demonstrates that there were little Euclidean distances between such groupings **(El-Safa et al., 2022)**. The samples have been tacking from deferent level in the sea, which showing that sediments are able to adsorb and retain significant amounts of toxic contaminants as heavy metals from water column differently along the aquatic ecosystem. The adsorption capacity depends on many factors of the sediment-water system, including pH, temperature, cation exchange capacity, ionic strength, surface area, grain size, mineralogical properties, activity of the benthic organisms.

Principal Component Analysis (PCA)

In 1933, Hotelling introduced the principal component analysis (PCA), a multivariate statistical approach (Huang and Wu, 2007). PCA can analyse multivariate relationships and explain data variation by limiting the number of variables to many groupings of persons based on principle component scores (Everitt and Dunn, 1992). Introduced by Rencher, this methodology may convert a data set with several variables into a set of comprehensive principal components and is quite comparable to the correlation or regression analysis methods. Researchers have used PCA in several fields because it enables a significant decrease in the number of variables and the identification of structure in the interactions between various variables (Rencher, 2002). The first step in using PCA to assess the levels of heavy metal contamination is to identify the principal components of the data set. Since the principal components make up the bulk of the data in the assessed indexes, they are able to properly represent the amounts of heavy metal contamination in the water. By using PCA techniques, we want to maximize the variance of a linear combination of the variables in the data set. The weight total of the different principle component values may be used to calculate the values of primary components, and the concentrations of heavy metals in the sea can be used to calculate the levels of heavy metal pollution in the sea.

The PCA of the metals demonstrated many PCA explaining in total 80.33% of the variance Table 7. and Fig. 5 (a, b, c, d, e, f, and g) In total seven factors, F1, F2, F3, F4, F5, F6, F7 explains 27.02, 18.09, 12.03, 9.90, 7.14, 5.79, 5.26, and 5.10% respectively Table 7 and Fig. 5 (a, b, c, d, e, f, and g) Where, the F1 represented by the Cr (-0.573), Cu (-0.858), Mn (-0.961), Ni (-0.937) and Zn (-0.843). the F2 consists by the TP (-0.935), Ba (-0.927), and Cd (-0.864). The F3, F4, F5, f6, F7, F8 represented by NO_2 (0.612), Hg (-0.603), Chl (0.611), NH_3 (0.572), NO_3 (0.675), and Al (-0.587) respectively. However, due to their low concentration in the seawater at both the top and bottom levels, many metals, such as iron and lead, are not important by any means. Individual metal contamination of marine networks may also be caused by human activities, the natural dispersion of clay minerals in sediment, and the interaction between soil and water.

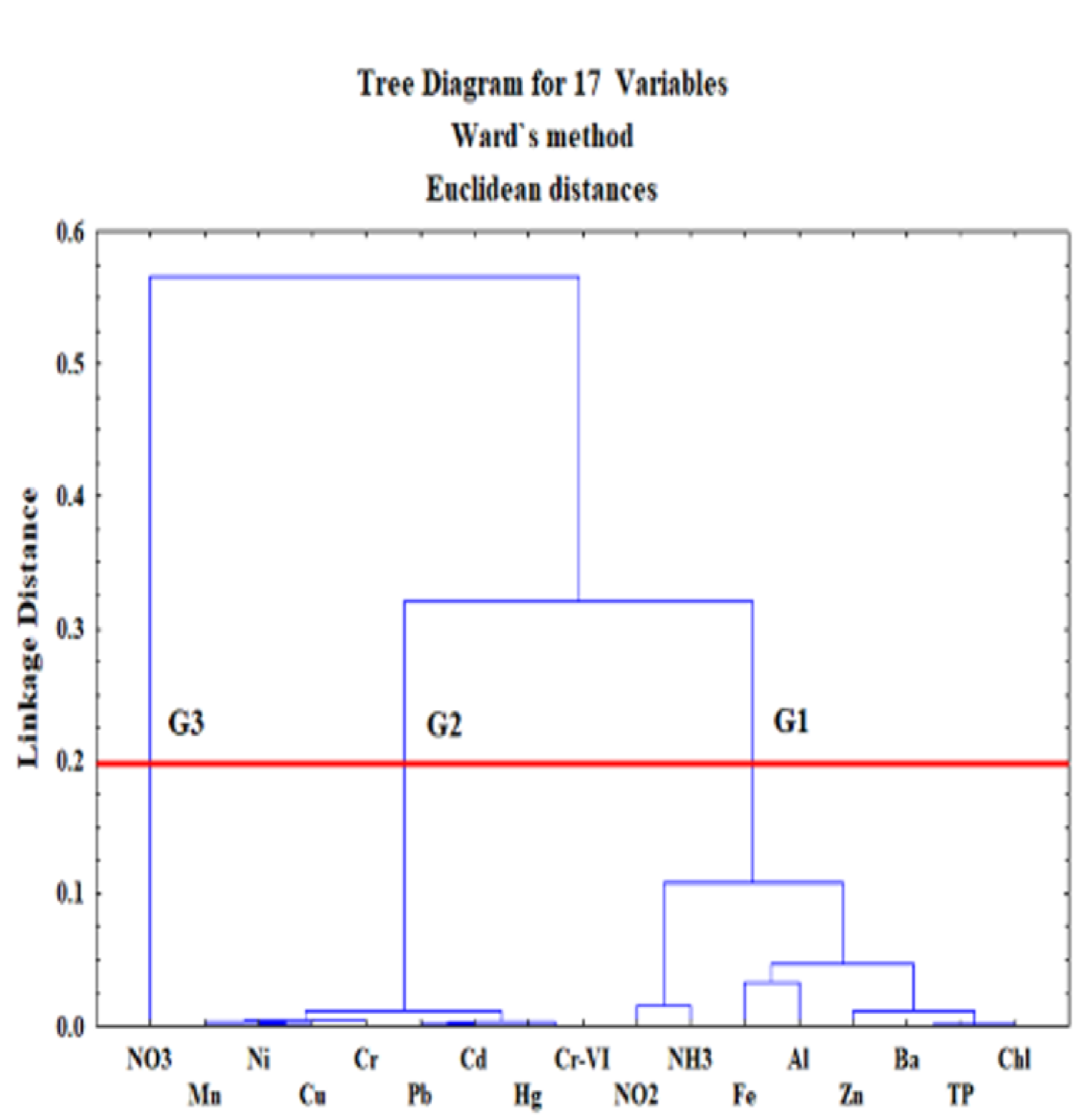

Fig. 4. Cluster Dendrogram for Variables.

Table 7. Correlation Between the Metal Parameters and Factors.

parameters	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Chl	-0.426	0.023	-0.254	0.279	**0.611**	-0.371	-0.143	-0.230
NH_3	0.188	-0.120	0.349	0.264	0.589	**0.572**	-0.099	-0.134
NO_3	-0.445	0.154	0.435	0.045	0.124	0.073	**0.675**	-0.004
NO_2	0.337	-0.098	**0.612**	0.007	-0.427	0.162	-0.238	-0.280
TP	0.119	**-0.935**	-0.082	0.030	-0.009	-0.035	0.093	0.105
***Cr-VI**	-0.476	-0.360	0.380	-0.347	-0.005	-0.359	-0.276	-0.337
Al	-0.199	-0.064	-0.256	0.525	-0.306	-0.097	0.323	**-0.587**
Ba	0.160	**-0.927**	0.031	0.110	0.134	-0.037	-0.041	0.149
Cd	0.086	**-0.864**	0.099	-0.148	0.009	0.214	0.156	-0.189
Cr	**-0.573**	-0.195	0.356	-0.500	0.168	-0.224	0.243	0.109
Cu	**-0.858**	-0.283	-0.064	0.025	-0.117	0.133	-0.214	-0.030
Fe	0.271	0.121	-0.576	-0.469	0.276	0.210	0.012	-0.342
Pb	0.298	-0.481	-0.447	0.440	-0.091	-0.123	0.051	0.183
Mn	**-0.961**	0.016	-0.107	0.108	0.000	0.069	-0.096	0.125
Hg	-0.105	-0.179	-0.603	**-0.631**	-0.155	0.182	0.109	-0.057
Ni	**-0.937**	-0.101	-0.094	0.138	-0.049	0.171	-0.055	0.006
Zn	**-0.843**	0.069	-0.148	0.100	-0.178	0.327	-0.070	0.098

*Cr (VI) Hexavalent Chromium.

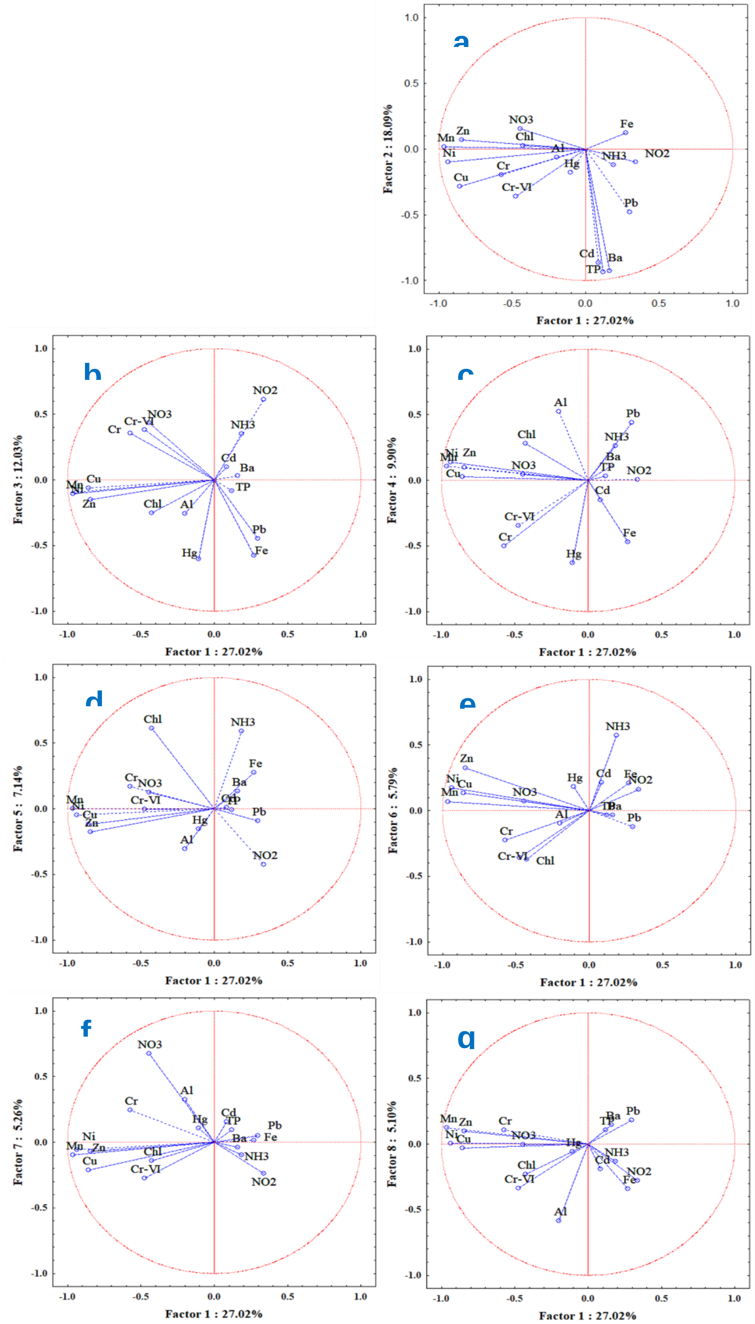

Fig. 5. (a, b, c, d, e, f, g). Variables Cluster Dendrogram for The Groups Were Identifiable Based On Their Hadrochemical Variable (At The Red Line).

Conclusion

In this research, multivariate statistical techniques such as CA and PCA based on physicochemical were tested to characterize the suitability of seawater quality for aquatic utilization in Mesaieed Industrial City (MIC) seawater. According to the acquired analytical data and the seawater in the analyzed area show that, 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.

The analysis revealed that in 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 the rest of parameters had a moderate affect, 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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