

Evaluation of chemical properties of Iraqi coastal water, North- western Arabian Gulf

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Abstract

This study aims to evaluate the chemical characteristics of Iraqi coastal waters in the northwestern Arabian Gulf for the year 2025, with a focus on the distribution of chemical elements, nutrients, and the environmental and anthropogenic factors controlling them. The significance of the research lies in its attempt to establish a national baseline for the oceanographic properties of Iraqi waters, thereby supporting sustainable marine resource management strategies and monitoring environmental changes. The study area covered a coastal strip of 60 km², where five strategic stations were selected, extending from Khor Al-Zubair to offshore waters. The Ocean Data View (ODV) program was employed to spatially represent the data. The results revealed clear variability in chemical properties: pH values ranged between 7.18 and 7.36, with the lowest values recorded at the inner stations due to port activities and carbon emissions. Station S1 exhibited the highest dissolved oxygen concentration (16.5 mg/L) and the highest carbon dioxide level (20 mg/L), reflecting the influence of ship movements and organic matter decomposition in the inner zones. Total dissolved solids (TDS) peaked at 32 ppm, while chloride concentrations reached 34,741 mg/L at the inner stations, gradually decreasing outward due to mixing with Gulf waters. Regarding nutrients, transitional stations recorded the highest nitrite values, whereas silica peaked (6.528 mg/L) at the inner stations, reflecting the impact of clayey sediments transported from the Shatt Al-Arab. The study concludes that inner and transitional stations are the most affected by human activities and riverine inputs, while offshore stations exhibit lower pollutant concentrations due to dilution processes. The strategic importance of these findings lies in providing accurate indicators of ocean acidification and oxygen depletion, underscoring the need to strengthen environmental monitoring networks to safeguard biodiversity and address climate challenges in the Iraqi coastal zone.

Keywords: Ocean Data View (ODV), Sea water, Arabian Gulf, chemical properties



Introduction

Oceans and seas represent the largest ecosystems on Earth, covering about 71% of the planet's surface and playing a fundamental role in regulating the global climate and sustaining marine life. Seawater possesses complex physical and chemical properties that control its behavior within marine environments. Understanding these properties is essential for studies related to marine ecosystems, marine chemistry, and coastal resource management (Webb, 2019). From a chemical perspective, seawater contains a variety of components including major ions, trace elements, dissolved salts, and gases such as oxygen and carbon dioxide. These components exist in a relatively stable chemical equilibrium governed by biological processes, sedimentation, dissolution, and gas exchange between the ocean and the atmosphere. Monitoring variations in these properties provides important indicators for assessing marine ecosystem health, understanding climate change, and detecting environmental pollution (Garcia-Soto *et al.*, 2021).

Seawater is composed of approximately 96.5% water and about 3.5% dissolved salts, in addition to small amounts of organic and inorganic substances, atmospheric gases, and suspended particles. The dominant dissolved ions include sodium, chloride, sulfate, magnesium, calcium, and potassium, which together account for nearly 99% of total dissolved salts. Other constituents such as boron, fluoride, bromide, strontium, and inorganic carbon species also contribute to seawater chemistry and influence key properties such as pH and chemical equilibrium (Encyclopaedia Britannica, 2025). Trace metals including iron, manganese, cobalt, nickel, copper, zinc, and cadmium play an important role in marine biogeochemical cycles and act as essential micronutrients for phytoplankton, with concentrations typically lower in surface waters due to biological uptake and higher at depth due to remineralization processes (Benaltabet *et al.*, 2025). Several chemical parameters are particularly important in controlling seawater chemistry. The hydrogen ion concentration (pH) is strongly influenced by the absorption of atmospheric carbon dioxide, which leads to ocean acidification. Since the mid-nineteenth century, ocean pH has decreased by about 0.1 units due to increasing CO₂ uptake (Delaigue *et al.*, 2025). Dissolved oxygen is another key parameter produced mainly through photosynthesis by phytoplankton in surface waters, while oxygen consumption at depth may lead to the formation of oxygen minimum zones that affect marine ecosystems (Belgacem *et al.*, 2025). Total alkalinity is also a fundamental parameter reflecting the capacity of seawater to neutralize acids and regulate the marine carbonate system, thereby influencing calcium carbonate precipitation and the ocean's buffering capacity (Lee *et al.*, 2024; Norbistrath *et al.*, 2024).

Carbon dioxide plays a central role in the marine carbonate system, and accurate measurement of CO₂ dynamics is essential for understanding ocean acidification and the ocean's role in the global carbon cycle. It is estimated that the ocean has absorbed nearly 25% of anthropogenic carbon dioxide emissions over recent decades, which slows atmospheric CO₂ accumulation but contributes to ocean acidification (Atwood *et al.*,

2024; Wang *et al.*, 2025). In addition, nutrients such as nitrogen and phosphorus regulate marine primary productivity and influence phytoplankton growth, thereby affecting global nutrient cycles and carbon exchange between the atmosphere and the ocean (Browning and Moore, 2023). Nutrient distributions in marine systems are strongly influenced by ocean circulation and climate-related processes, particularly in coastal and semi-enclosed seas where water exchange with the open ocean controls nutrient variability (Leng *et al.*, 2023).

From this perspective, the present study aims to:

1. Assessment of Current Water Quality

- Evaluate the qualitative chemical properties of Iraqi coastal waters in the northwestern Arabian Gulf for the year 2025.

- Establish the present status of water quality

2. Spatial Distribution of Nutrients and Major Chemical Constituents

- Analyze the distribution of nitrite, nitrate, phosphate, and silica, along with other essential chemical parameters.

- Employ Ocean Data View (ODV) software to generate accurate spatial maps of these datasets.

3. Impact of Anthropogenic and Port Activities

- Investigate the influence of shipping traffic and industrial operations in Umm Qasr and Khor Al-Zubair ports.

- Focus on variations in carbon dioxide concentrations and pH levels as indicators of seawater acidification.

4. Role of Riverine Inputs and Natural Processes

- Examine the contribution of Shatt Al-Arab River inflows to changes in salinity, chlorides, and total dissolved solids (TDS).

- Assess the effects of tidal mixing cycles on these parameters.

5. Establishment of a National Baseline Database

- Develop a reference baseline for the oceanographic characteristics of Iraqi territorial waters.

- Support sustainable marine resource management strategies.

- Enhance environmental monitoring networks to address climate-related challenges such as hypoxia (oxygen depletion).

Materials And Methods

Description of study area

Iraq possesses a narrow coastal strip that provides it with maritime access to the outside world. Maritime boundaries significantly influence international political relations due to disputes that often arise over territorial waters. Iraq's coastline is particularly limited, offering a narrow maritime frontage of approximately 60 km² along the Arabian Gulf. This stretch extends from Ras al-Bisha in the east to Khor al-Zubair in the west, facing the Gulf directly for a distance of 12.4 nautical miles toward Khor

Abdullah. Territorial waters serve multiple strategic purposes for the states that possess them. They may be rich in minerals—especially oil—and act as vital conduits for maritime transport, international connectivity, and access to marine resources such as fish and other seafood. The extent of territorial waters varies, necessitating a clear distinction between different maritime zones. Measuring and delineating territorial waters is often challenging due to the irregular nature of coastlines, which may include rocky outcrops, inlets, islands, sandy shores, and areas affected by tides and other natural features that complicate boundary determination (Asaad, 2025). Five stations were strategically selected for the study along the navigational channel, extending from the upper reaches of Khor Al-Zubair to the deep waters of the Arabian Gulf.

The first station is located at the extreme northwestern edge near the entrance of Umm Qasr Port. It represents the starting point of the narrow navigational channel and lies at a longitude of 48° and a latitude of 30° . This station is directly influenced by port activities and commercial shipping traffic. The second station lies to the southeast of the first station, at a longitude of 48° and a latitude of 29° . It is a transitional zone characterized by intense navigational activity. The third station is situated near the eastern shores of Bubiyan Island, also at a longitude of 48° and a latitude of 29° . It marks the opening from the inlet toward the wider navigational channel, where water depths begin to increase gradually and are influenced by coastal mud sedimentation. The fourth station is located within the Khor Al-Asma'i area, along the outer navigational routes, at a longitude of 48° and a latitude of 29° . It serves as a connecting point between the internal channels and the open waters. The fifth station lies in the southeastern part of the study area, extending toward the deep waters of the Arabian Gulf. It may serve as a reference point for comparison with the inner stations in terms of the physical and chemical properties of seawater, as shown in (figure 1), the table (1) below shows the coordinates of the study sites.

Table (1): Coordinates of the study sampling sites.

Longitude and Latitude	Location Name	Location No.
$30^\circ 03' 02.05'' \text{N } 48^\circ 13' 03.51'' \text{E}$	Nearby UM QASR	S1
$29^\circ 92' 30.06'' \text{N } 48^\circ 29' 73.28'' \text{E}$	Nearby Khor Azubair	S2
$29^\circ 80' 90.29'' \text{N } 48^\circ 47' 84.49'' \text{E}$	Nearby Bubiyan	S3
$29^\circ 68' 90.45'' \text{N } 48^\circ 73' 26.56'' \text{E}$	Nearby AL ASMAEY	S4
$29^\circ 72' 25.12'' \text{N } 48^\circ 82' 91.18'' \text{E}$	Near the port of Al-Amia	S5

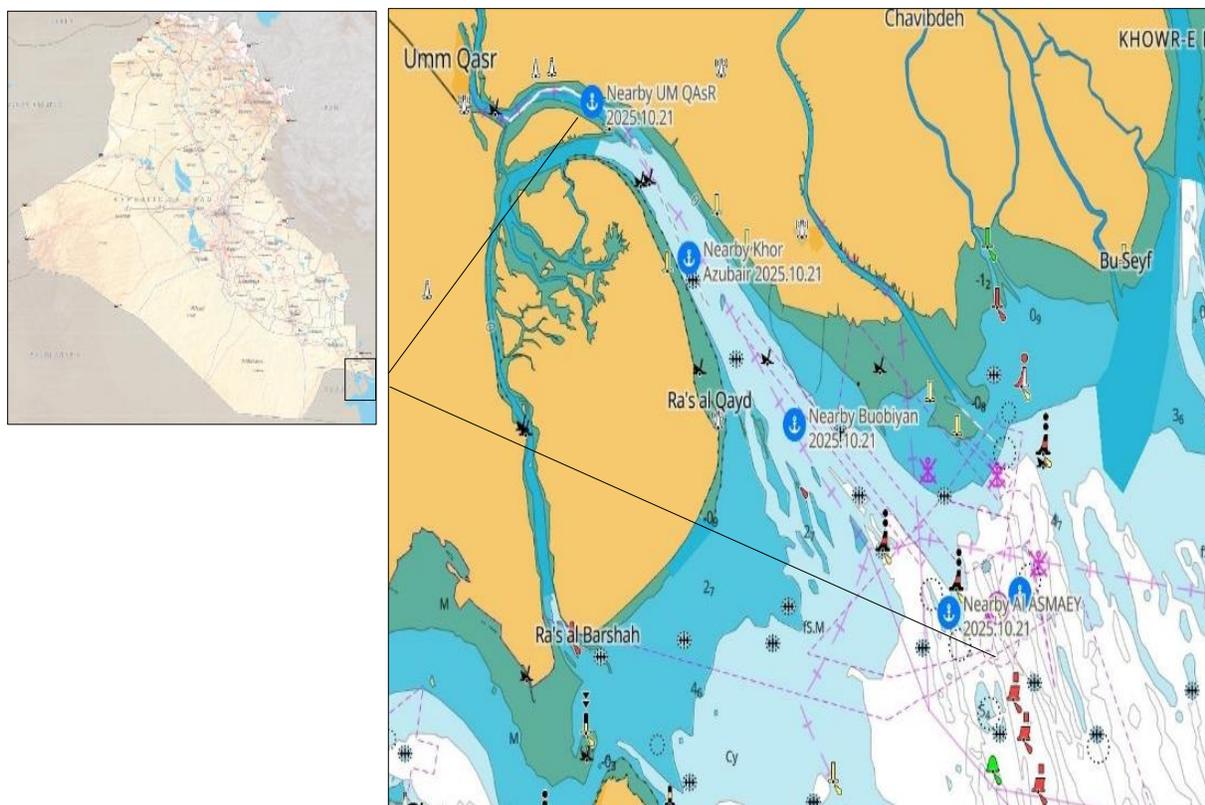


Figure (1): illustrates the selected study stations.

Sampling:

Water samples were collected using plastic bottles (5L) Preservation and fixation of samples for laboratory analysis., while transparent Winkler glass bottles (250 ml) were employed to measure dissolved oxygen (DO) concentrations. The bottles were filled below the water surface, ensuring the absence of air bubbles. Subsequently, oxygen was fixed in the field by adding 2 ml of manganese sulfate and 2 ml of alkaline azide iodide solution, after which the bottle was sealed and shaken 10–15 times, then left until a precipitate appeared. Thereafter, 2 ml of concentrated sulfuric acid was added, and the bottle was shaken again 10–15 times until the precipitate dissolved and disappeared (APHA *et al.*, 2017).

Field and laboratory work

pH

Water pH was determined using a multi-parameter meter (Multi meter), previously calibrated with standard buffer solutions of pH 4, 7, and 9 (APHA *et al.*, 2017).

Total Dissolved Solids (TDS)

TDS concentrations were measured by immersing the probe of the multi-parameter meter directly into the water, with results expressed in ppm.

Carbon Dioxide (CO₂)

To assess potential CO₂ loss during titration under field conditions, a serological pipette (2–5 ml) was employed as an approximate titration tube. A second sample was taken immediately after the first titration, phenolphthalein indicator was added, and the titrant from the initial titration was introduced. The appearance of a pink color indicated no CO₂ loss; absence of color required continuation of titration until the endpoint was reached.

Dissolved Oxygen (DO)

DO was determined using the Azide modification of the Winkler method (APHA *et al.*, 2017). Oxygen was fixed in Winkler bottles in the field, transported to the laboratory, and 100 ml of sample was titrated with sodium thiosulfate (0.0125 N) using starch as an indicator. Results were expressed in mg/L.

Total Alkalinity

Total alkalinity was measured following Lind (1979). A 100 ml sample was titrated with standard sulfuric acid using phenolphthalein and methyl orange indicators. Carbonate alkalinity was determined at pH 8.3, while total alkalinity was determined at pH 4.5.

Chloride (Cl⁻)

Chloride was quantified by titration of 2 ml of sample with silver nitrate, using potassium chromate as an indicator. The endpoint was identified by the appearance of a reddish-pink color.

Nitrate (NO₃)

Nitrate was determined by reduction through a cadmium column, followed by colorimetric analysis. A 100 ml sample was treated with ammonium chloride, sulfanilic acid, and indicator solution, and absorbance was measured at 543 nm using a spectrophotometer.

Nitrite (NO₂)

Nitrite was measured colorimetrically by treating a 50 ml sample with sulfanilic acid and diphenylamine indicator. After color development, absorbance was recorded at 543 nm.

Phosphate (PO₄)

Phosphate was analyzed following Murphy and Riley (1962) as described in APHA *et al.* (2017). Optical density was measured at 885 nm, with results expressed as µg-atP/L.

Silicate (SiO₂)

Silicate was determined according to Murphy and Riley (1955) as described in APHA *et al.* (2017). Optical density was measured at 810 nm, with results expressed as µg-atSi/L.

Results and Discussion

Table (2) shows the average values of chemical factors measured during the study period for the five study sites.

Table (2): Results of Chemical Measurements.

Parameter	ST1	ST2	ST3	ST4	ST5
Water Temp (°C)	24.3	23	26.3	27.5	28
pH	7.18	7.2	7.25	7.36	7.33
DO (mg/L)	16.5	11.48	12.5	14.04	13.06
CO ₂	20	20	15	13	13
Total Alkalinity(mg/L)	230	210	215	190	205
TDS (ppm)	32	31.4	30.9	29.8	29.8
Cl(ml)	34741	30132.5	28005.5	25169.5	25524
NO ₂ (µg/L)	0.37	1.05	1.09	0	0
NO ₃ (µg/L)	1.116	2.528	1.782	1.782	2.052
PO ₄	0.0499	0.0766	0.0522	0.964	0.0322
Sio ₂	6.096	6.528	6.048	4.224	2.976

1. Hydrogen Ion concentration (pH)

The ratios presented in Table (1) indicate that pH values range between 7.18 at Station 1 and 7.36 at Station 4. The data show that the decrease in pH at the inner stations reflects the influence of port activities and CO₂ emissions, whereas the higher values at the outer stations reflect natural ventilation and reduced accumulation of carbon dioxide (Shetye *et al.*, 2024). Figure (2) presents a map illustrating the spatial distribution of pH values generated using the ODV software.

2. dissolved oxygen

The highest dissolved oxygen concentration was recorded at Station 1 (16.5 mg/L), while the lowest value was observed at Station 2 (11.48 mg/L), as shown in the table. The elevated dissolved oxygen at Station 1 may be attributed to strong mixing during the spring tide, whereas the reduction at Station 2 reflects the intensity of maritime traffic and oxygen consumption through organic matter decomposition (Lachkar *et al.*, 2022). Figure (3) presents a map illustrating the distribution of dissolved oxygen values generated using the ODV software.

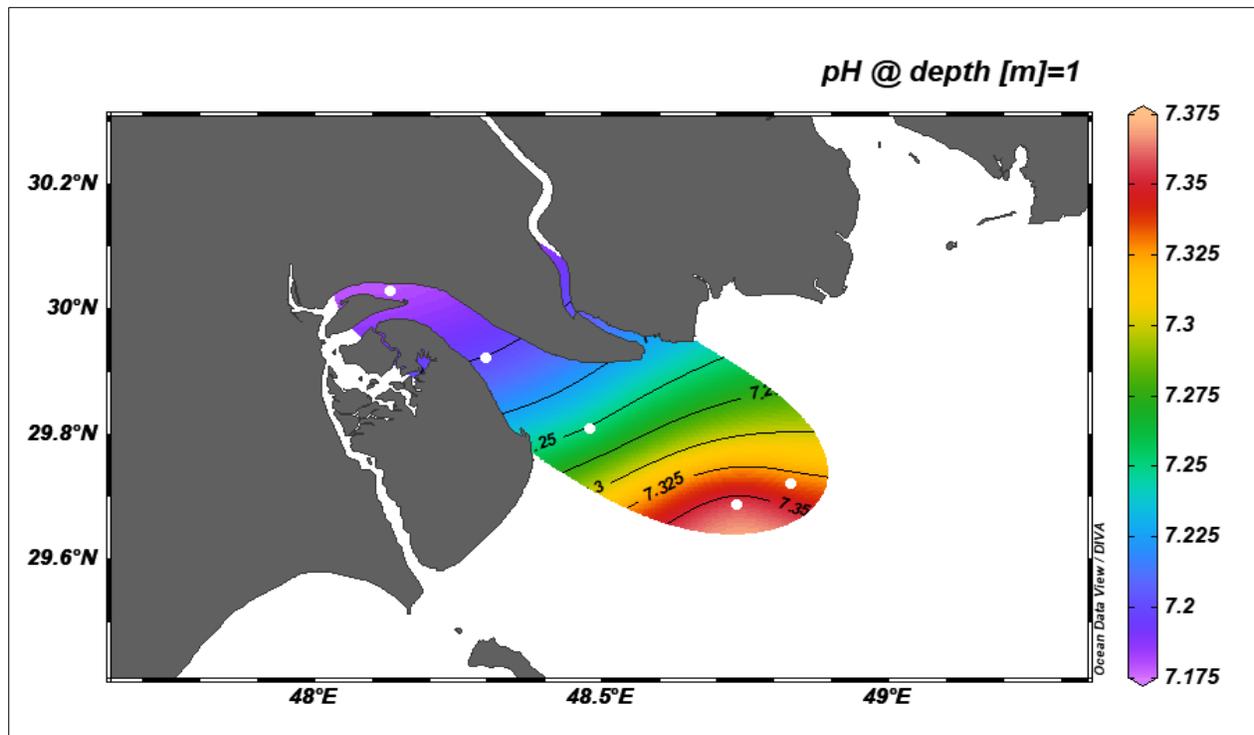


Figure (2): Map Showing Gradients of pH Values at the Study Stations Using ODV Software.

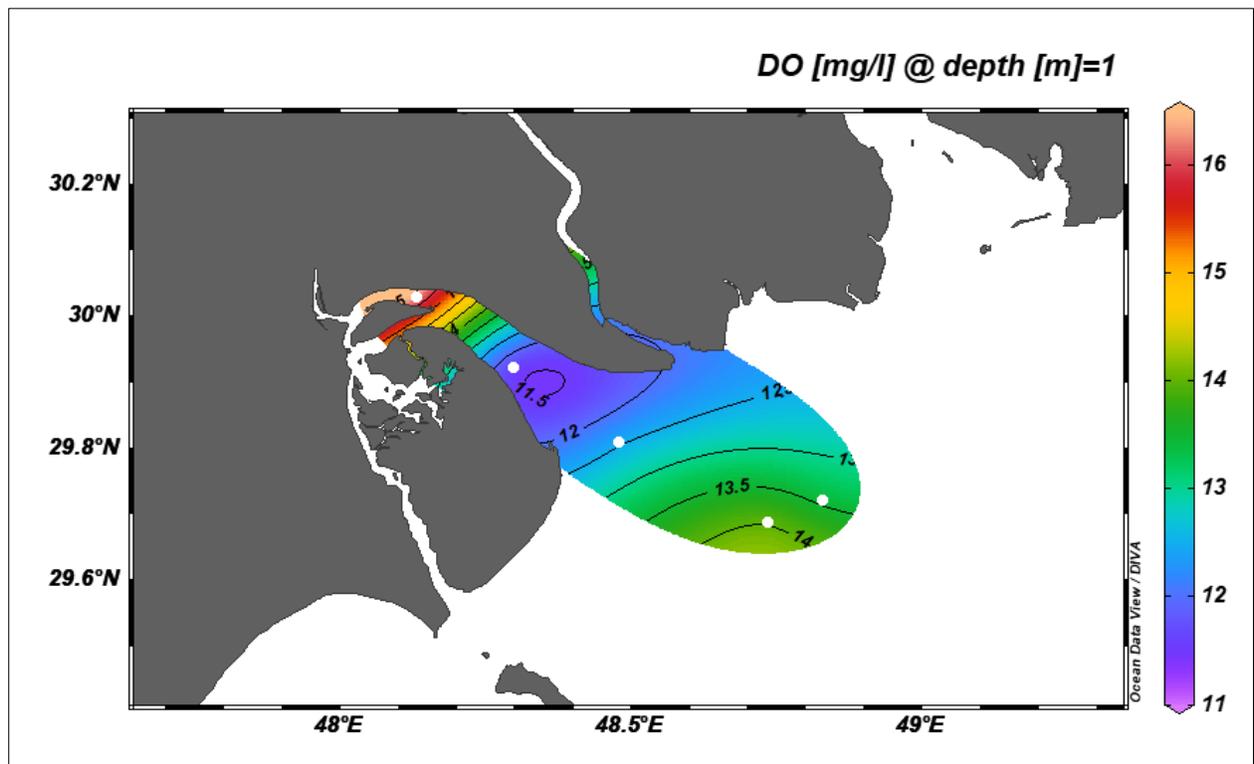


Figure (3): Map Showing Gradients of Dissolved Oxygen Values at the Study Stations Using ODV Software.

3. carbon dioxide

The highest concentration of carbon dioxide was measured at Station 1 (20 mg/L), indicating that the inner stations are influenced by ship emissions and organic matter decomposition. In contrast, the lowest value was recorded at Station 4 (13 mg/L), demonstrating that the outer stations are better ventilated and lose carbon dioxide to the atmosphere (Al-Thani *et al.*, 2020). Figure (4) presents a map illustrating the distribution of carbon dioxide values generated using the ODV software.

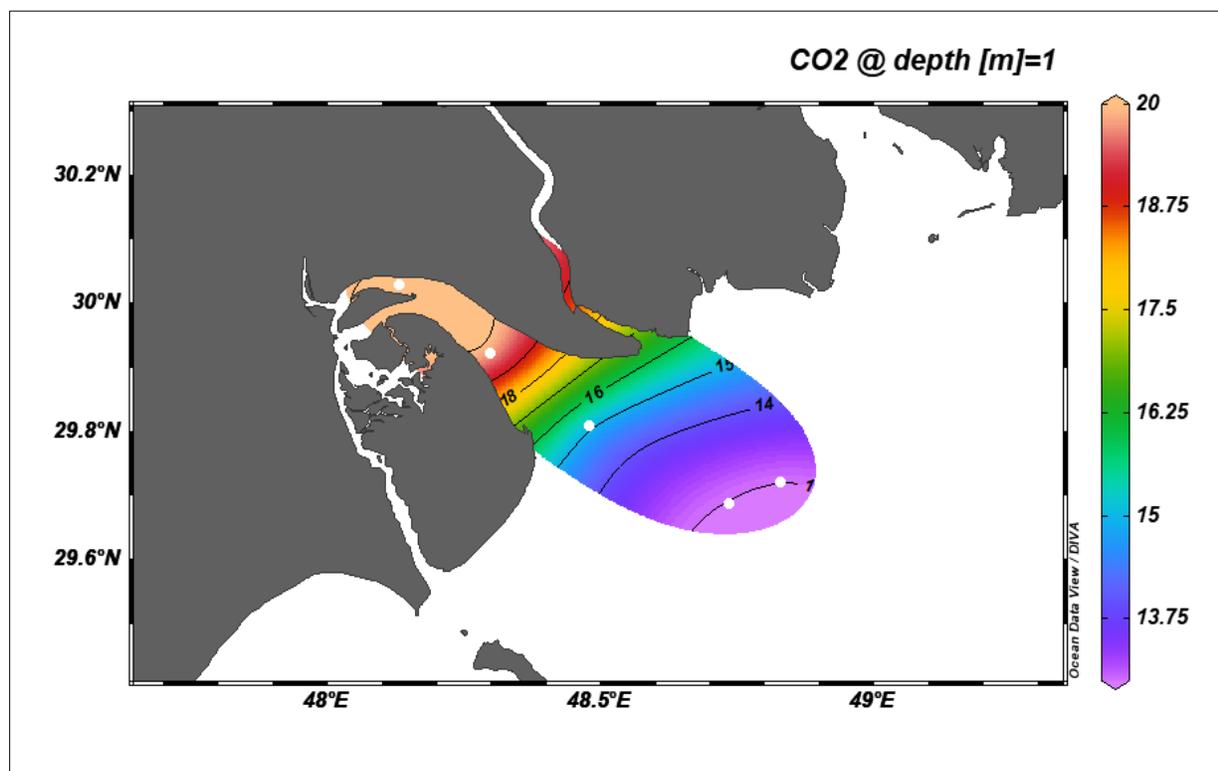


Figure (4): Map Showing Gradients of CO₂ at the Study Stations Using ODV Software.

4. Total alkalinity

Exhibited its highest value at Station 1 (230 mg/L) near the port areas, reflecting the accumulation of bicarbonate and carbonate ions as a result of anthropogenic activities. In contrast, the lowest value was recorded at Station 4 (190mg/L) in the open areas, due to dilution and mixing processes (Izumi *et al.*, 2022). Figure (5) presents a map illustrating the distribution of total alkalinity values generated using the ODV software.

5. Total dissolved solids

The highest concentrations of total dissolved solids were recorded at Station 1 (32 ppm), as the inner stations are more exposed to salinity intrusions from the Shatt al-Arab and port areas. The concentrations gradually decreased to 29.8 ppm at Station 5, where the outer stations are relatively less saline due to mixing with Gulf waters (Al Kubaish &

Salama, 2024). Figure (6) presents a map illustrating the distribution of total dissolved solids values generated using the ODV software.

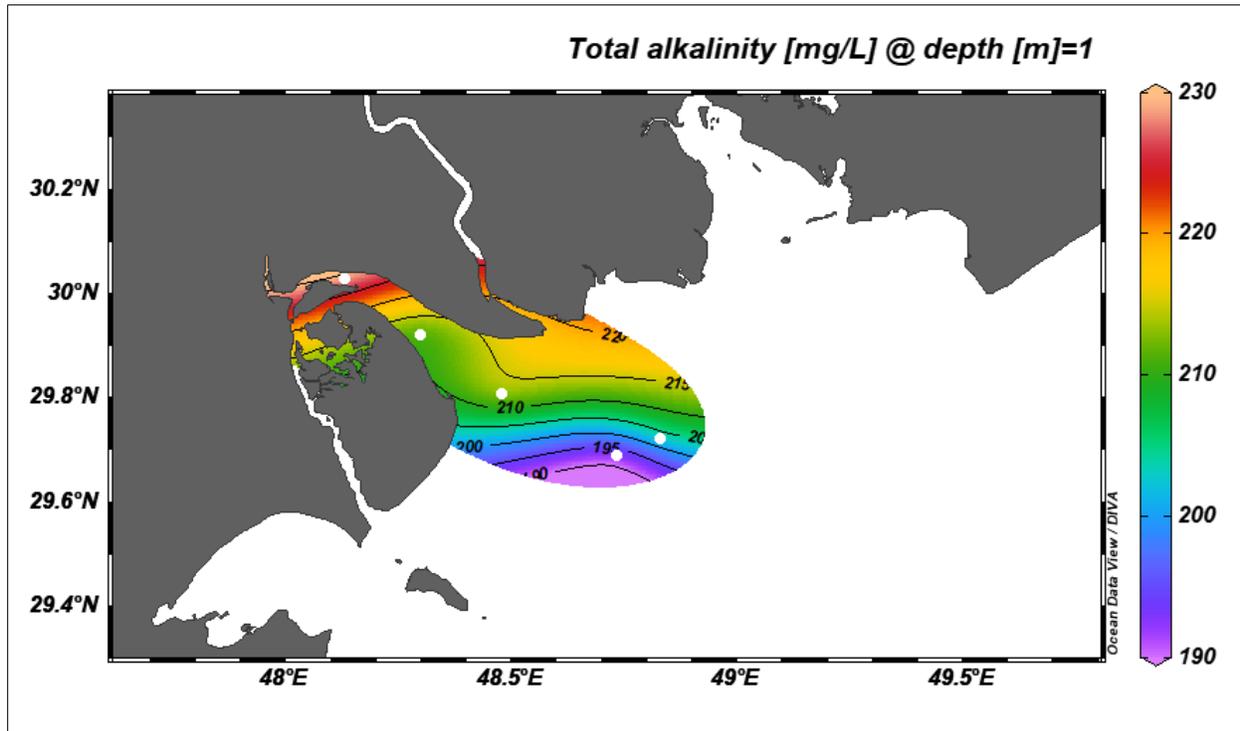


Figure (5): Map Showing Total Alkalinity at the Study Stations Using ODV Software.

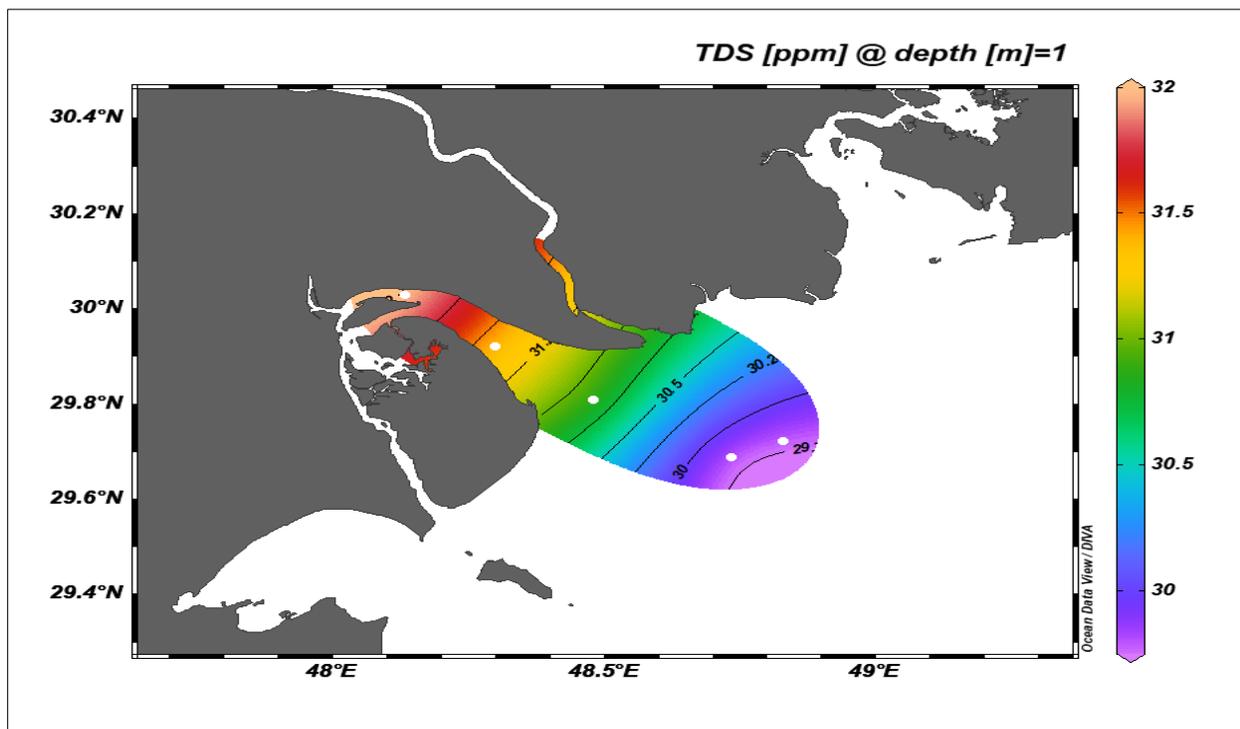


Figure (6): Map Showing TDS Values at the Study Stations Using ODV Software.

6. Chloride

Chloride concentrations were higher at the inner stations, with a recorded value of 19.8, reflecting the influence of saline waters from the Shatt al-Arab. In contrast, lower concentrations were observed at the outer stations, with a value of 14.4, due to dilution processes (Hamdan, 2016). Figure (7) presents a map illustrating the distribution of chloride values generated using the ODV software.

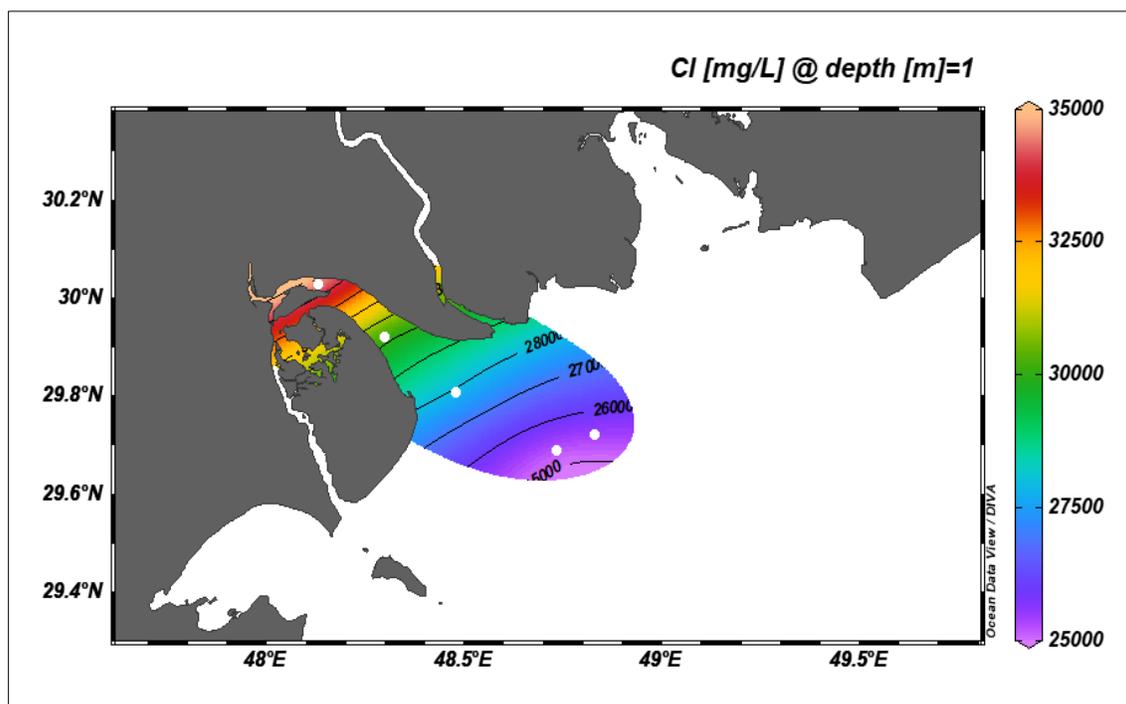


Figure (7): Map Showing Chloride Values at the Study Stations Using ODV Software.

7. Nutrients

The nutrient results revealed a marked variation among the stations during the spring tide period. Figures (8, 9, 10, 11) show the results of the nutrient values.

Nitrite (NO_2)

Nitrite concentrations recorded the highest values at the transitional stations (S2, S3) compared to the inner and outer stations, reflecting the bacterial decomposition of organic matter in semi-enclosed areas and highlighting the role of coastal activities in nitrogen enrichment in the Arabian Gulf (Al-Yamani *et al.*, 2019).

Nitrate (NO_3)

Nitrate showed a distinct increase at S2 (2.528 mg/L), indicating a continuous input of nutrients from port activities and riverine sources (Gomes *et al.*, 2018).

Phosphate (PO_4)

Phosphate reached its highest concentration at S4 (0.964 mg/L), which reflects the influence of wastewater discharge and anthropogenic activities in coastal zones (Al-Sarawi *et al.*, 2020).

Silica (SiO₂)

Silica exhibited the highest values at the inner stations (S1, S2, S3), ranging between 6.096–6.528 mg/L, which indicates the transport of silty sediments from the Shatt Al-Arab into the navigation channel (Gomes *et al.*, 2018). Collectively, these results demonstrate that the inner and transitional stations are more affected by anthropogenic activities and riverine inputs, whereas the outer stations show lower nutrient concentrations due to dilution and water mixing during the spring tide (Al-Yamani *et al.*, 2019). The nutrient results revealed a marked variation among the stations during the spring tide period. Nitrite (NO₂) concentrations recorded the highest values at the transitional stations (S2, S3) compared to the inner and outer stations, reflecting the bacterial decomposition of organic matter in semi-enclosed areas and highlighting the role of coastal activities in nitrogen enrichment in the Arabian Gulf (Al-Yamani *et al.*, 2019). Nitrate (NO₃) showed a distinct increase at S2 (2.528 mg/L), indicating a continuous input of nutrients from port activities and riverine sources (Gomes *et al.*, 2018). Phosphate (PO₄) reached its highest concentration at S4 (0.964 mg/L), which reflects the influence of wastewater discharge and anthropogenic activities in coastal zones (Al-Sarawi *et al.*, 2020).

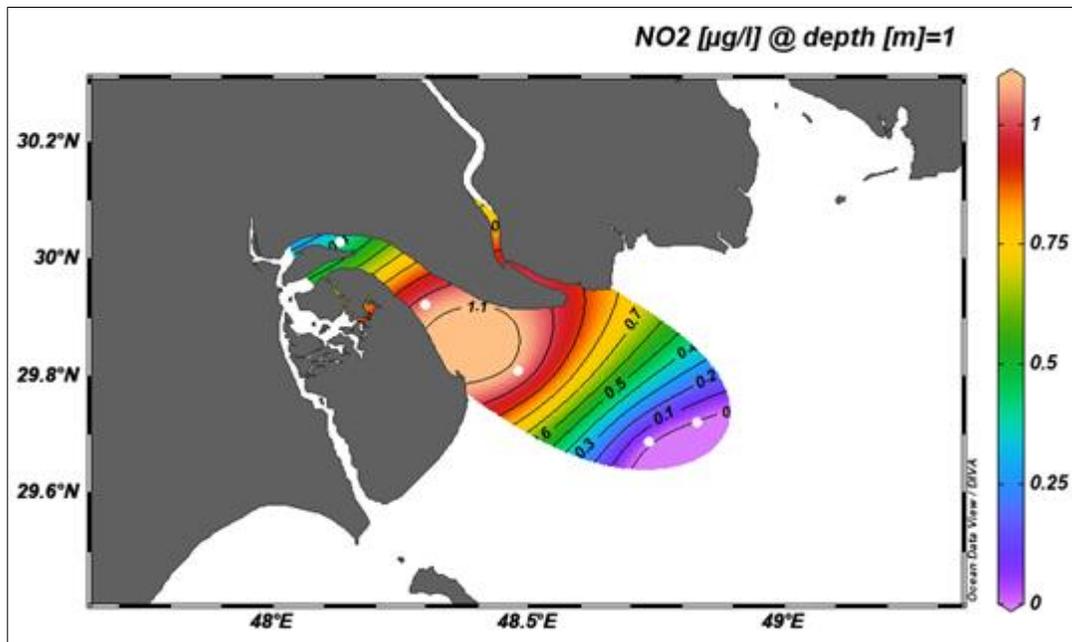


Figure (8): Map Showing Nitrite Values at the Study Stations Using ODV Software.

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concentrations due to dilution and water mixing during the spring tide (Al-Yamani *et al.*, 2019).

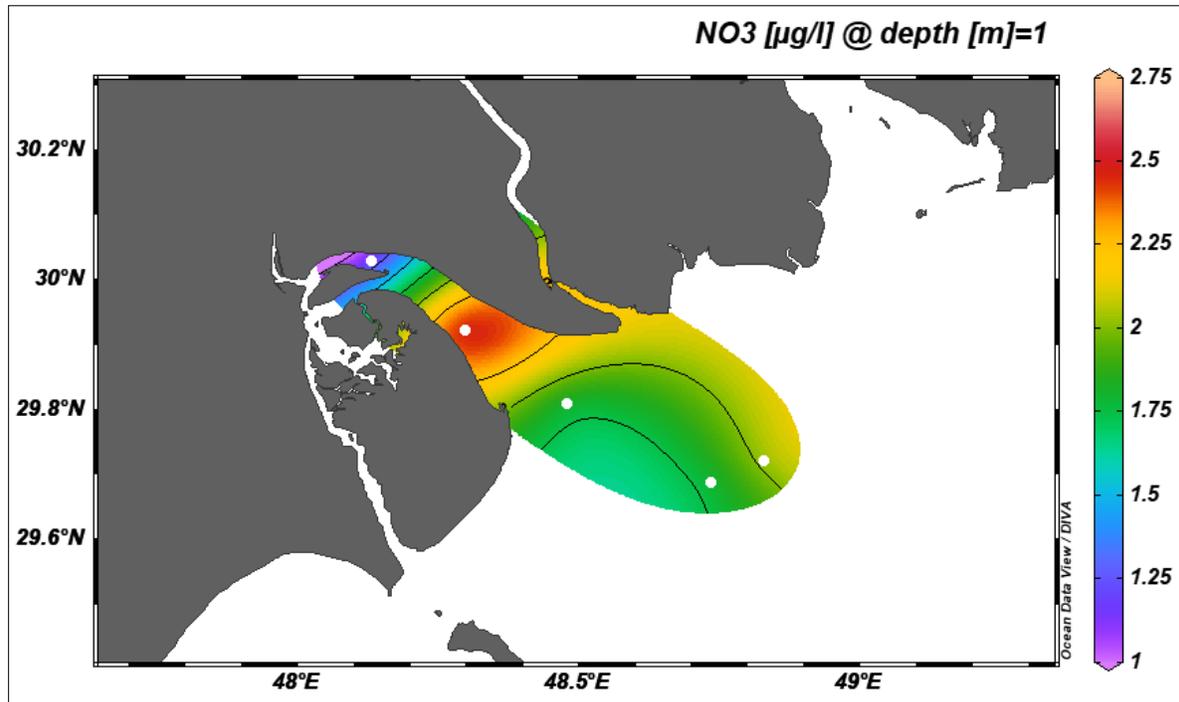


Figure (9): Map Showing Nitrate Values at the Study Stations Using ODV Software.

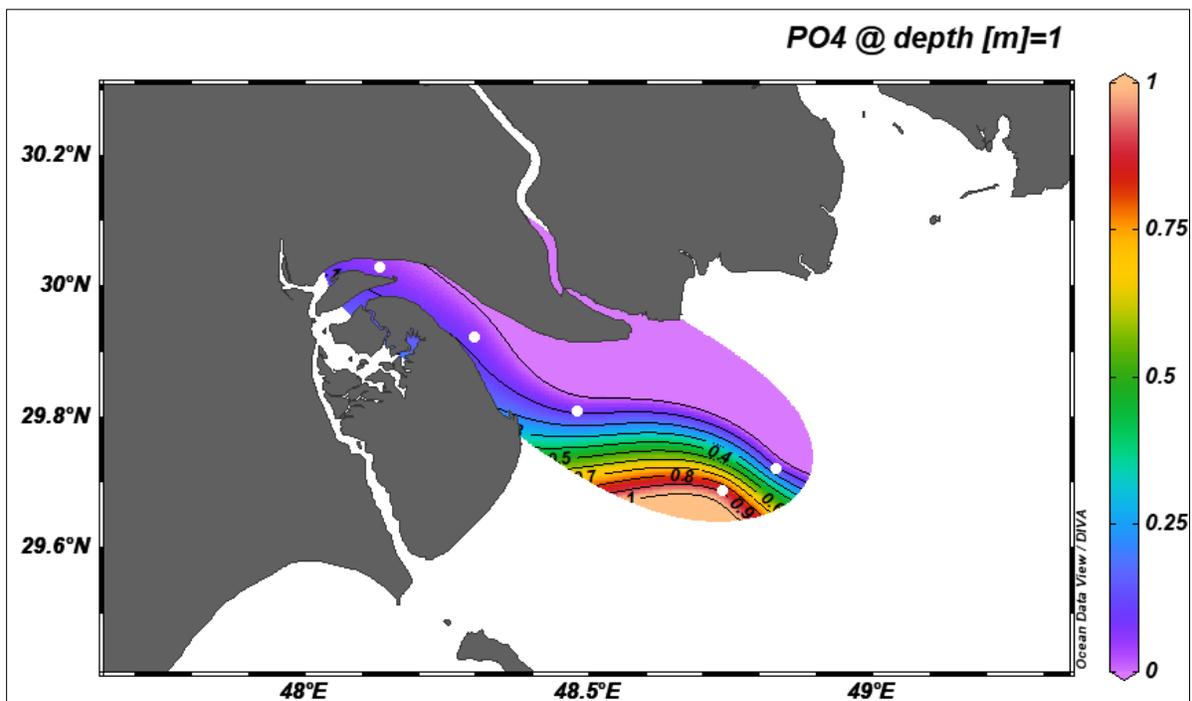


Figure (10): Map Showing Phosphate Values(mg/l) at the Study Stations Using ODV Software.

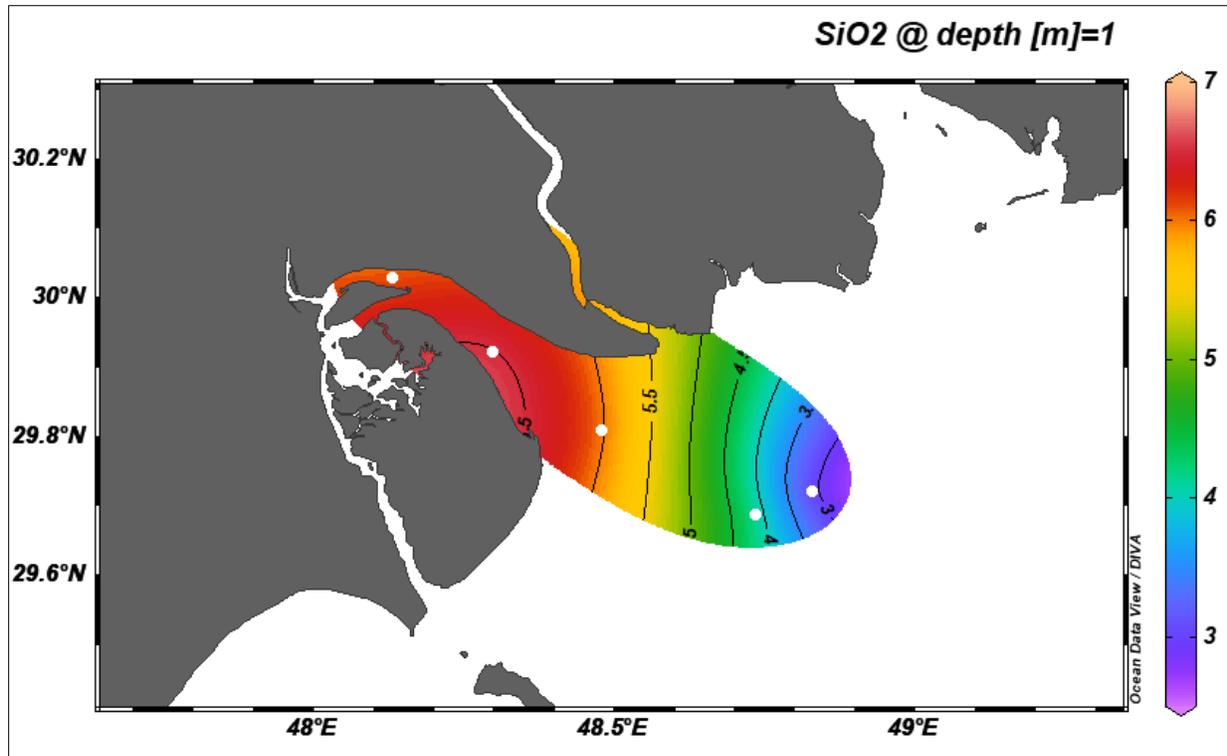


Figure (11): Map Showing Silica Values at the Study Stations Using ODV Software.

Conclusions

The study concludes that Iraqi coastal waters exhibit tangible chemical variability directly influenced by geographic location, anthropogenic activities, and hydrographic conditions. The main finding can be summarized as follows:

- **Impact of human and port activities:** The inner stations, particularly those near Umm Qasr port and Khor Al-Zubair, are the most affected by human activity. They recorded the highest levels of carbon dioxide (20mg/L) and total alkalinity (230mg/L), as a result of ship emissions and the decomposition of organic matter.
- **Indicators of water acidification:** The results revealed a decrease in pH at the inner stations (7.18) compared to the outer ones, serving as an early indicator of ocean acidification driven by increased carbon dioxide absorption in areas of intense maritime traffic.
- **Influence of riverine inputs and salinity:** Inputs from the Shatt Al-Arab play a major role in elevating concentrations of total dissolved solids (TDS), chlorides, and due to dilution and mixing with Arabian Gulf waters.
- **Nutrient distribution and eutrophication:** Nutrients (nitrite, nitrate, and silica) are concentrated in the inner and transitional zones as a result of river discharges, sewage effluents, and port activities. In contrast, the outer stations exhibit lower concentrations, owing to marine currents and tidal cycles that disperse these elements.

- **Stratigic importance of monitoring:** The study emphasizes that monitoring changes in dissolved oxygen and nutrient levels is not a scientific luxury but a challenges such as hypoxia and climate chang in the region.

From the above, it becomes clear that human activities and riverine inflows are the primary dirvers of chemical variabliity along the Iraqi coasts, necessitating the strengthening of environmental monitoring networks to ensure the sustainable management of marine resource.

Recommendations

Based on the results and outcomes of this study, the following focused recommendations can be summarized:

1. Strengthening continuous environmental monitoring networks: Intensify the monitoring of pH levels and dissolved oxygen in coastal stations to track ocean acidification and the expansion of hypoxic zones resulting from climate change and anthropogenic activities.
2. Controlling port pollution and maritime activities: Enforce stricter environmental regulations on ship emissions and port operations at Umm Qasr and Khor Al-Zubair stations (S1, S2) to reduce concentrations of carbon dioxide and dissolved solids generated by operational processes.
3. Managing wastewater discharges: Ensure proper treatment of sewage and waste from coastal activities prior to disposal, particularly in areas that recorded elevated phosphate and nutrient levels such as Station 4 (S4).
4. Expanding hydrographic studies: Conduct more specialized research on the influence of riverine inputs from the Shatt Al-Arab and their interaction with Gulf waters to better understand the transport of siliceous sediments and their impact on navigation channels.
5. Developing coastal resource management strategies: Adopt modern approaches to marine environmental management based on observed chemical indicators to ensure the sustainability of fisheries and biodiversity within Iraqi territorial waters.

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تقييم الخصائص الكيميائية للمياه الساحلية العراقية شمال غرب الخليج العربي

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المستخلص

تهدف هذه الدراسة إلى تقييم الخصائص الكيميائية للمياه الساحلية العراقية في شمال غرب الخليج العربي لعام 2025، مع التركيز على توزيع العناصر الكيميائية والمواد المغذية والعوامل البيئية والبشرية المتحكمة فيها. تكمن أهمية البحث في سعيه إلى وضع خط أساس وطني للخصائص الأوقيانوغرافية لمياه العراق، بما يدعم استراتيجيات الإدارة المستدامة للموارد البحرية ورصد التغيرات البيئية. شملت منطقة الدراسة شريطاً ساحلياً بمساحة 60 كم²، حيث تم اختيار خمس محطات استراتيجية تمتد من خور الزبير إلى المياه البحرية المفتوحة. وقد استُخدم برنامج Ocean Data View (ODV) لتمثيل البيانات مكانياً. أظهرت النتائج تبايناً واضحاً في الخصائص الكيميائية؛ إذ تراوحت قيم الأس الهيدروجيني (pH) بين 7.18 و7.36، وسُجلت أدنى القيم في المحطات الداخلية نتيجة الأنشطة المينائية وانبعاثات الكربون. سجلت المحطة الأولى أعلى تركيز للأكسجين المذاب (16.5 ملغم/لتر) وأعلى مستوى لثاني أكسيد الكربون (20 ملغم/لتر)، مما يعكس تأثير حركة السفن وتحلل المواد العضوية في المناطق الداخلية. بلغت قيمة المواد الصلبة الذائبة الكلية (TDS) جزءاً في المليون، فيما وصلت تراكيز الكلوريد إلى 34,741 ملغم/لتر في المحطات الداخلية، مع انخفاض تدريجي نحو الخارج بفعل الاختلاط مع مياه الخليج. أما بالنسبة للمواد المغذية، فقد سجلت المحطات الانتقالية أعلى قيم للنترت، في حين بلغت السيليكا ذروتها (6.528 ملغم/لتر) في المحطات الداخلية، مما يعكس تأثير الرواسب الطينية المنقولة من شط العرب. خلصت الدراسة إلى أن المحطات الداخلية والانتقالية هي الأكثر تأثراً بالأنشطة البشرية والمدخلات النهرية، بينما تُظهر المحطات البحرية الخارجية تراكيز أقل من الملوثات بفعل عمليات التخفيف. وتكمن الأهمية الاستراتيجية لهذه النتائج في توفير مؤشرات دقيقة لظاهرة تحمّض المحيطات ونقص الأكسجين، مما يبرز الحاجة إلى تعزيز شبكات الرصد البيئي لحماية التنوع الحيوي ومواجهة تحديات المناخ في المنطقة الساحلية العراقية.

الكلمات المفتاحية: عرض بيانات المحيط (ODV)، مياه البحر، الخليج العربي، الخصائص الكيميائية.