International Journal of
**Environmental Science**
*(IJES)*

# Spatial and Temporal Variation of Physicochemical Parameters and Trace Metals in Shatt al-Arab Estuary and Adjacent Coastal Areas Southern Iraq

Alaa Jumaah Al-waeli and Yousif sh. J. Al-Jorani

IPRJB
INTERNATIONAL PEER REVIEWED JOURNAL AND BOOK PUBLISHING

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.9, Issue 1, No.4. pp 84 - 105, 2026

www.iprjb.org

# Spatial and Temporal Variation of Physicochemical Parameters and Trace Metals in Shatt al-Arab Estuary and Adjacent Coastal Areas Southern Iraq

Alaa Jumaah Al-waeli and Yousif sh. J. Al-Jorani
Department of Applied Marine Sciences, College of Marine Sciences, University of Basra, Iraq

**Article History**

***Received 29th January 2026***

***Received in Revised Form 28th February 2026***

***Accepted 31st March 2026***

How to cite in APA format:

Al-waeli, A., & Al-Jorani, Y. (2026). Spatial and Temporal Variation of Physicochemical Parameters and Trace Metals in Shatt al-Arab Estuary and Adjacent Coastal Areas Southern Iraq. *International Journal of Environmental Sciences*, *9*(1), 84–105. https://doi.org/10.47604/ijes.3701

**Abstract**

**Purpose:** The physical and chemical factors have a significant role in defining the aquatic environmental features in estuarine and coastal environments, particularly in the light of climate change effects in addition to human activity. The proposed study will evaluate the environment and the levels of certain trace elements in water within the Shatt al-Arab estuary and Iraqi coastal waters in southern Iraq.

**Methodology:** Four water locations were sampled along the stretch from the Naqaa area to the breakwater at the Grand Faw Port in two seasons: summer (September 2025) and winter (January 2026). Various chemical and physical parameters were examined, including water temperature, pH, turbidity, electrical conductivity (EC), total suspended solids (TSS), biochemical oxygen demand (BOD5), and dissolved oxygen (DO). Also, trace element concentrations (Pb, Cu, Mn, Zn, Fe, Cd, Ni) were identified.

**Findings:** The findings indicated an evident spatial and temporal difference in water quality features. During the summer, the highest electrical conductivity values (58.8-58.9 mS/cm) were observed at stations 3 and 1, respectively. The value of dissolved oxygen was highest in winter (10.4 mg/L) and lowest at station 2 (estuary area) in summer (6.6 mg/L). Turbidity of water was maximum (396.6 NTU) in the winter at station 2. The trace elements also showed significant seasonal variations, except at stations 1 and 2, where the highest iron concentration (6.688 mg/L) was found in the estuary region during winter and the lowest (1.093 mg/L) during summer. In the meantime, the maximum lead level (4.385 mg/L) was first observed at station 1 in the summer and evidently decreased during the winter.

**Unique Contribution to Theory, Practice and Policy:** This paper gives a detailed evaluation of the spatial and temporal changes in the physical and chemical characteristics along with the distribution of trace elements and the effect on the environmental factors on water quality in estuarine and coastal water systems, which help in supporting environmental monitoring programs and decision-making processes in resource management and reducing the water contamination in southern Iraq.

**Keywords:** *Factor Analysis, Trace Metals, Shatt Al-Arab Estuary, Coastal Areas*

## INTRODUCTION

Estuaries are transitional aquatic and environmental systems that mix freshwater from rivers with seawater. Estuaries also represent a complex interaction between terrestrial and marine systems. These environments are among the most productive aquatic systems on Earth due to the high nutrient levels carried by river discharges. At the same time, these environments are considered among the most affected by pollutants resulting from human activities, whether through river pollution or various activities in coastal areas (Castro and Huber, 2003; Al-Shammari et al., 2020). Estuaries are also dynamic, with physical and chemical properties that can change along their length due to variations in slope, water discharge, and the geological characteristics of the riverbed, as well as differences between river water and seawater (Al-Shawi, 2010).

The coastal marine environment is of significant economic importance to many countries due to the resources it provides for fishing, navigation, energy, and tourism (EPA, 2004). In this context, the Shatt Al-Arab River estuary and the Iraqi coastal waters are considered to be environmentally important systems characterized by hydrological complexity, as they are greatly affected by tides and the intrusion of seawater from the Arabian Gulf, which leads to noticeable variations in the physical and chemical properties of water over short time periods (Samer Adnan et al., 2019; Lateef et al., 2020). Moreover, studying the aquatic environment helps in understanding the nature of the energy available and transferred within these ecosystems (Keithan & Lowe, 1985).

The Iraqi coastline extends for about 64 km and lies along the northwestern coast of the Arabian Gulf, which can be considered a semi-closed sea, with land along most of its shores. It is typified by shallow water, with depths averaging around 35 meters and a maximum of around 100 meters in the south, closer to the Strait of Hormuz (Al-Nafisi, 2009; Purser and Seibold, 1973; Al-Shamary et al., 2020). The region around the Shatt al-Arab delta is also notably shallow, and the Shatt al-Arab is regarded as the primary source of fresh water pumped into the Arabian Gulf, with large volumes of clay and sand (Hartmann et al., 1971). The Arabian Gulf lies between 24 ° and 30 ° N and is of great economic, environmental, and political importance, serving as one of the most important routes for the transport of commerce and oil (Ghani, 1988; Al-Nafisi, 2009).

The study area, although having a high environmental and economic significance, could be faced with mounting stresses because of the hydrological alterations, decline in river discharge, and the emergence of additional pollution sources. Besides, alterations caused by human actions and contemporary coastal development projects are also monitored. The majority of earlier studies have been restricted on some part of the water quality or a narrow spatial or temporal scale without including the integrated analyses that combine the spatial and temporal variability and correlate it to factors that would influence it. Furthermore, numerous research articles of the past (Purser & Seibold, 1973; Ghani, 1988) are not indicative of the current environment changes that are being witnessed in the region. Thus, there is a high demand of recent and perhaps thorough research to present the latest information on a seasonal and spatial variation of physical and chemical properties and trace element concentrations (Al-Zlemat, 2019).

The current study aimed to identify both the physical and chemical characteristics, as well as the concentrations of some trace elements in both the waters of the Shatt al-Arab river estuary and the waters of the Iraqi coast after the estuary, in addition to analyzing the spatial and

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.9, Issue 1, No.4. pp 84 - 105, 2026


temporal variation of all variables, which enhances many of the updated databases that in turn support environmental monitoring programs as well as the work on the sustainability of water resources.

## METHODOLOGY

Iraqi marine waters represent the northwestern part of the Arabian Gulf (Figure 1). The study area is located at the end of the southern part of the Shatt al-Arab River and Iraqi marine waters, which differ from the rest of the Arabian Gulf due to the influence of sediments carried by the Shatt al-Arab (Hussein et al., 1991).The seabed characteristics vary between the stations in the study area due to the influence of sediments carried by the Shatt al-Arab River, which leads to higher clay content in the northern parts compared to the southern parts, which have less. Coral was also discovered in the open water area of the study stations, which is common in most parts of the Arabian Gulf (Jawad et al., 2018). Northwestern winds dominate the area and cause water movement from three directions, pushing the warm surface waters northward, leading to mixing with Shatt al-Arab waters, in addition to the Coriolis effect, which drives the entire water mass westward (Hussain et al., 1989). On both sides of the estuary, the sediments of the Shatt al-Arab spread, causing shallow areas that extend to the mud (Mohammed et al., 2002).

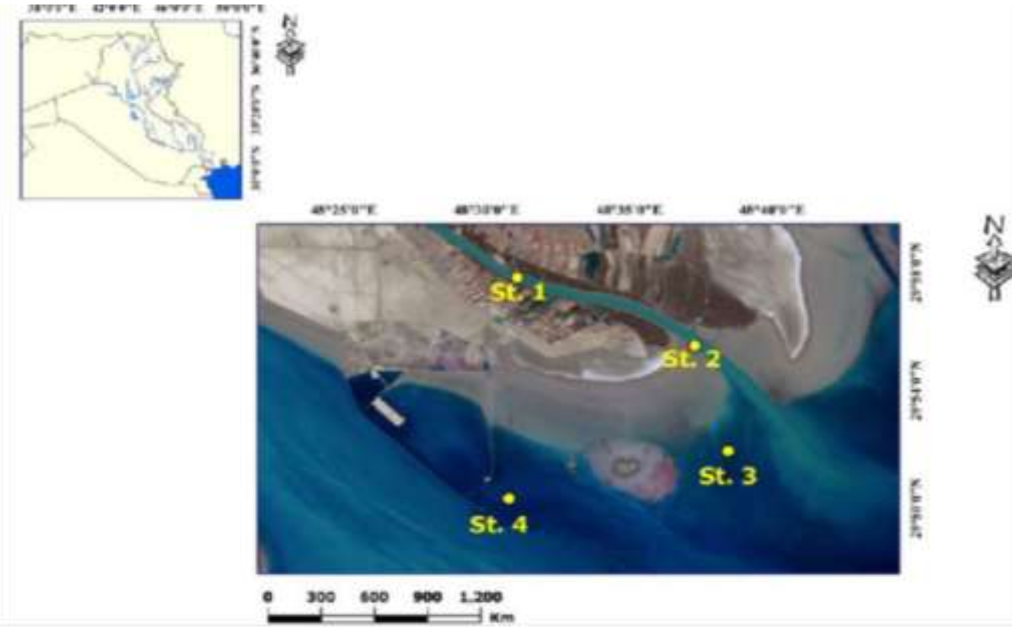


*Figure 1: Shows the Study Area*

Four stations were selected in this study, located in the area represented by the geographical coordinates using GPS as shown in Table 1.

Samples for the current study were collected during the summer and winter seasons from four stations in September 2025 and January 2026 at a depth ranging from 20 to 30 centimeters below the water surface during low tide. This layer represents the area of direct interaction between freshwater on one side and saltwater on the other in estuarine environments. It is also considered the most affected layer by pollutants resulting from human activities, such as surface runoff and other contaminated discharges. Sampling from the subsurface layer is regarded as a common method in water quality studies, as it provides an appropriate representation of the environmental conditions affecting the aquatic ecosystem (APHA, 2023;

Chapman, 1996; UNEP, 2008). Although there may be a vertical gradient in the physical and chemical properties in the study area, sampling from the surface and subsurface layers is considered suitable for assessing water quality in general, especially in spatial and temporal comparative studies (Chapman, 1996). Additionally, using this depth in all study stations also ensures the standardization of measurement processes.

A medium-sized vessel was used for the collection operation. A set of environmental properties at the site was measured. Water samples were preserved immediately after collection by adding nitric acid ($HNO_3$) to lower the pH to below 2, according to the standard method to prevent metal precipitation or loss (APHA, 2023). The samples were also stored in clean, tightly sealed polyethylene bottles and kept at low temperatures until analysis.

First station : Al-Naqaa (Upstream of the Estuary): It is located within the Shatt Al-Arab channel prior the coastal opening. It represents the limit of relatively fresh water control under normal conditions. It is active with commercial ship traffic heading to Abu Flous Port, as well as fishing boats that dock at the Al- Naqaa quay for fish.

Second station – Shatt al-Arab estuary: This station represents the primary transitional zone where there is a direct mixing interface between riverine and marine waters, showing the clearest salinity gradient and daily changes associated with the tide. This station is mainly influenced by the flow of the Shatt al-Arab River, which passes through the Roka Channel 10 meters deep amidst shallow waters on both sides, 4 meters deep, during high tide. The benthic substrate consists of muddy sediments, and the water column is characterised by a distinct brownish hue resulting from high turbidity (Al-Shamary et al., 2020; Al-Waeli, Ismail, et al., 2020; Al-Waeli, Khalid, et al., 2020).

Third station – This station is located along the Coast navigation channel extending to the right of the estuary, being influenced by waves action and marine currents and is shallow. This station is characterized by a depth of 10 meters, with some trenches on the seabed reaching depths of about 20 meters, along with a prevalence of clayey to sandy sediments due to erosion caused by current flow (Al-Badran, 1995).

Fourth Station – Near the breakwater: This station is situated adjacent to the western breakwater of Al-Fao Grand Port, where changes in current patterns and sedimentation are expected due to the sheltering effect of the breakwater, and depths are greater as a result of continuous dredging of the commercial ship channels to and from the port.

**Table 1: Geographic Coordinates of Study Stations Using GPS**

| Longitude ( E ) East | Latitude ( N ) North | Stations |
|---|---|---|
| E"06.5'48°31 | N"35.0'29°57 | 1 .St |
| E"23.6'48°37 | N"23.5'29°55 | 2 .St |
| E"38.0'48°38 | N"49.8'29°51 | 3 .St |
| E "01.1'48°31 | N"05.1'29°50 | 4 .St |

Physicochemical parameters, including water temperature, pH, salinity, electrical conductivity (EC), and total dissolved solids (TDS), were measured in situ using a calibrated multi-parameter water quality meter. Total suspended solids (TSS) were determined gravimetrically following the standard methods established by the American Public Health Association (APHA, 2023). Turbidity was quantified using a digital turbidity meter and reported in Nephelometric Turbidity Units (NTU). For trace element analysis, concentrations were determined using an Atomic Absorption Spectrophotometer (AAS), model Phoenix-986 (UK origin), ensuring high sensitivity and precision.

This study focused on measuring the total concentration of trace elements, as the samples were not filtered before preservation. The limits of detection (LOD) for each element were determined according to standard laboratory procedures. The quality of the results was also ensured through the use of certified reference materials (CRMs) and calibration standards to verify standard accuracy and reliability.

## RESULTS AND DISCUSSION

Physical properties were documented through both in-situ and laboratory analyses. Surface water temperature and electrical conductivity were measured on-site using a portable multi-parameter device. Conversely, turbidity was quantified in the laboratory using a high-precision German- manufactured turbidimeter. Furthermore, Total Suspended Solids (TSS) were determined in the laboratory following the gravimetric method incorporating filtration, oven-drying, and precision weighing in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2023).

The minimum water temperature values were recorded during the winter months 13.3C°, 14.3C°, 14.2C°, 16.2C° across the four stations respectively, while the highest values were recorded during the summer, with the first station recording the highest value 35.9C° as shown in Figure 2. Statistical analysis revealed a highly significant interaction effect ($P<0.01$) of the interaction between the class and the stations on temperature.

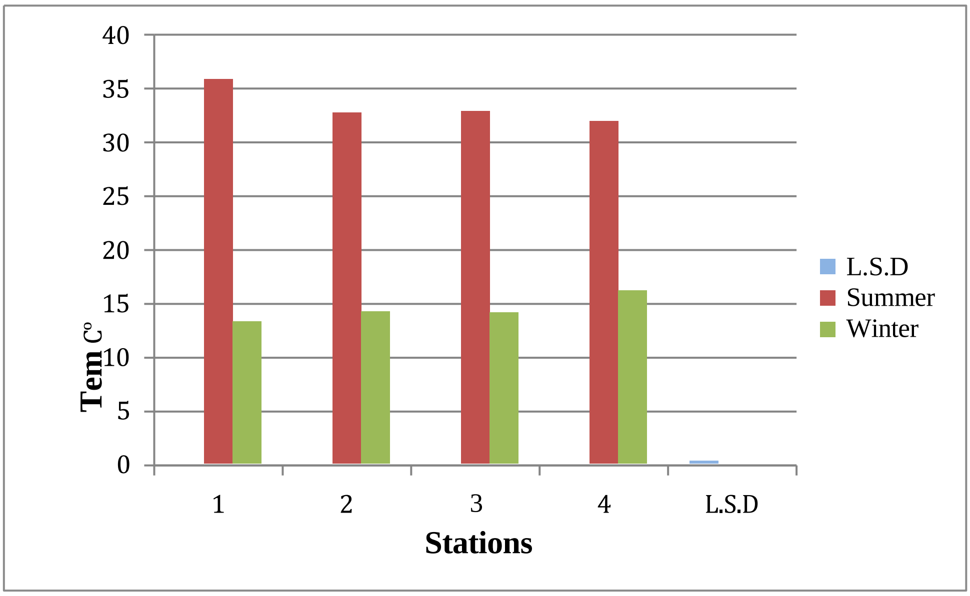


*Figure 2: Seasonal Variation in Temperature Values at the Study Stations*

This seasonal difference aligns with the thermal behavior of the Iraqi coastal water environment, which ranges approximately between 14–34°C depending on the season, where the rise in temperature in summer is associated with longer daylight hours and increased radiation, while it decreases in winter due to shorter daylight hours and reduced surface heating. (Abbas et al., 2020) The rise in temperature during summer enhances evaporation and increases the concentration of salts and dissolved substances, as well as lowers the solubility of oxygen, and also increases the rate of microbial decomposition of organic matter. These are among the mechanisms that help in understanding and explaining the decrease in dissolved oxygen during summer compared to winter (Al-Fartusi, 2018). Surface temperatures along the Shatt al-Arab also show noticeable variations due to natural factors and human activities, with higher temperature values in urban areas compared to water areas. The presence of water bodies also contributes to reducing the intensity of local temperature and achieving a relative thermal balance in the surrounding areas (Al-Daraji et al., 2024). The results of the current study showed seasonal variations in salinity concentrations among the selected study stations. Peak salinity levels were recorded during the summer, reaching 36.1 ppt at Station 3, 36 ppt at Station 4, 35.2 ppt at Station 2 (the estuary), and 35.9 ppt at Station1. The lowest concentrations were recorded in winter, 11.8 ppt at Station 1, while the highest in winter reached 35.7 ppt and 33.1 ppt at Stations 4 and 3, respectively, as shown in Figure 3.

The results of the statistical test (F-test) showed highly significant differences ($P < 0.01$) for the effect of the interaction between seasons and stations on salinity values . This pattern indicates that the hydrological regime is governed by the river- seawater mixing gradient. In winter, salinity drops sharply at the first station 1 (Al-Naqaa) and progressively increases seaward, becoming almost marine at the fourth station. The intrusion of seawater into the Shatt al-Arab River is also a phenomenon documented in recent literature due to the decline in freshwater releases, which pushes the saline wedge to advance upstream. (Khalaf et al., 2021). The increase in salinity during summer at all stations is due to evaporation, reduced discharge, and the intensified long-distance marine influence, while the low values during winter near the Nuk'ah Station (Al-Faw) reflect an increase in freshwater dilution, which also aligns with the idea of the inverse role of discharge on TDS/TSS and others (Al-Fartusi, 2018).

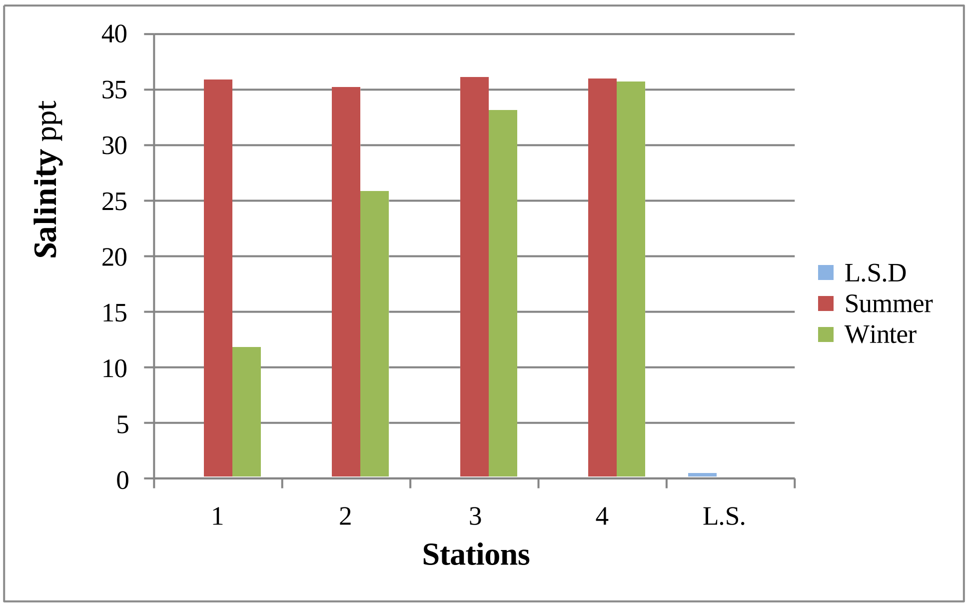


*Figure 3: Seasonal Variation in Salinity Values at the Study Stations*

Turbidity levels showed highly significant differences ($P < 0.01$) for regarding the interaction between season and stations during the study period. The maximum turbidity values were recorded (396.6 NTU) and (165 NTU) at the second and fourth stations during winter, respectively. In contrast, the minimum turbidity values were observed during the summer reaching 15.73 NTU and 19.5 NTU at the 4 and stations 2, respectively as shown in Figure 4.

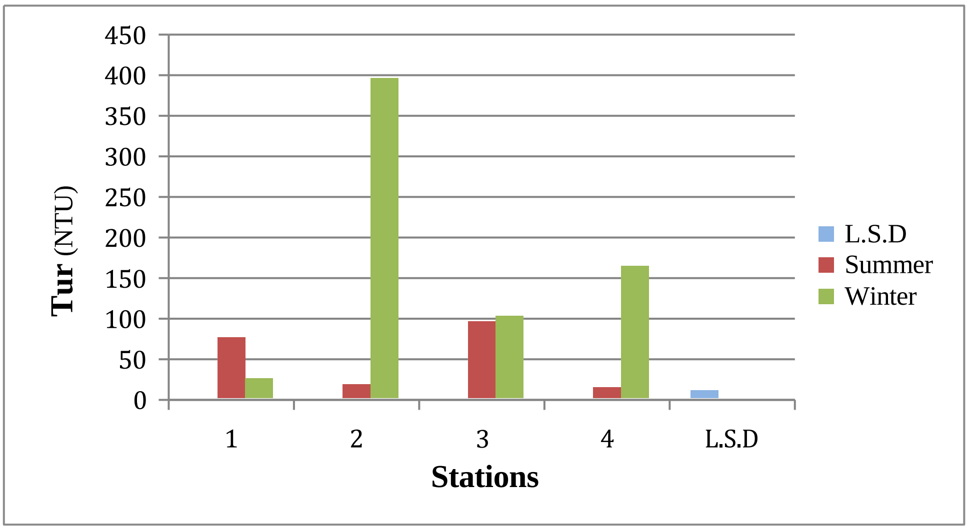


*Figure 4: Seasonal Variation in Turbidity Values at the Study Stations*

The substantial winter surges in turbidity at Station 2 (the estuary) and Station 4 near the breakwater indicate the dominance of sediment resuspension processes as well as plankton transport due to strong tidal currents, waves, and wind. In addition, the impact of navigation activities and the possibility of increased surface runoff are also noted. Modeling of the Shatt al-Arab has shown that TSS increases as we move toward the estuary and that tidal flow conditions alter plankton values (Al Fartusi, 2018). The presence of plankton in the estuary area and adjacent coastal waters can also create some localized disturbances and affect sediment dynamics (Qasim S Ali, 2022). Some local studies support describing the estuary area as shallow, with silty clay deposits, and its water color tends to be brown due to the turbidity resulting from the agitation of the sediments (Al-Shammari, 2020). Navigational channel areas near ports are also known for high turbidity due to ship movement and tidal currents (Abbas et al ,. 2020 ). And this is consistent with the fact that the estuary and the area around the breakwater are regions with high hydrodynamic energy. One of the most important explanations for turbidity is that it is not merely a physical property, but it is considered a geochemical carrier because many heavy metals adsorb onto the surfaces of suspended particles. An Iraqi study on coastal waters showed that there is a clear positive relationship between turbidity and TDS on one hand, and (Cd and Fe) on the other hand, and concluded that an increase in turbidity is directly associated with an increase in the adsorption of cadmium and iron onto the surfaces of plankton. (Al Abdulaziz et al., 2021)

The study results revealed a significant convergence in electrical conductivity (EC) values during the summer, ranging between 56.6 and 58.9 mS/cm, reflecting purely marine water characteristics across all monitoring stations. In contrast, the winter season exhibited a distinct spatial variation; conductivity dropped sharply at Station 1 to 20.8 mS/cm, followed by a gradual increase downstream toward the mouth, reaching 57.8 mS/cm at Station 4. This seasonal disparity is attributed to the absolute marine dominance during summer, driven by the salt wedge intrusion and the mixing of Shatt al-Arab waters with the Arabian Gulf. This was further exacerbated by high evaporation rates and diminished freshwater river discharge. Conversely, a pronounced dilution effect was evident in winter due to increased freshwater input from rainfall and runoff. This led to a reduction in salinity at inland stations, while coastal

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.9, Issue 1, No.4. pp 84 - 105, 2026
www.iprjb.org

stations remained strongly influenced by prevailing marine conditions (Fakher(b) et al., 2026), (Rahi S Halihan, 2018) and (Khalaf et al., 2021)

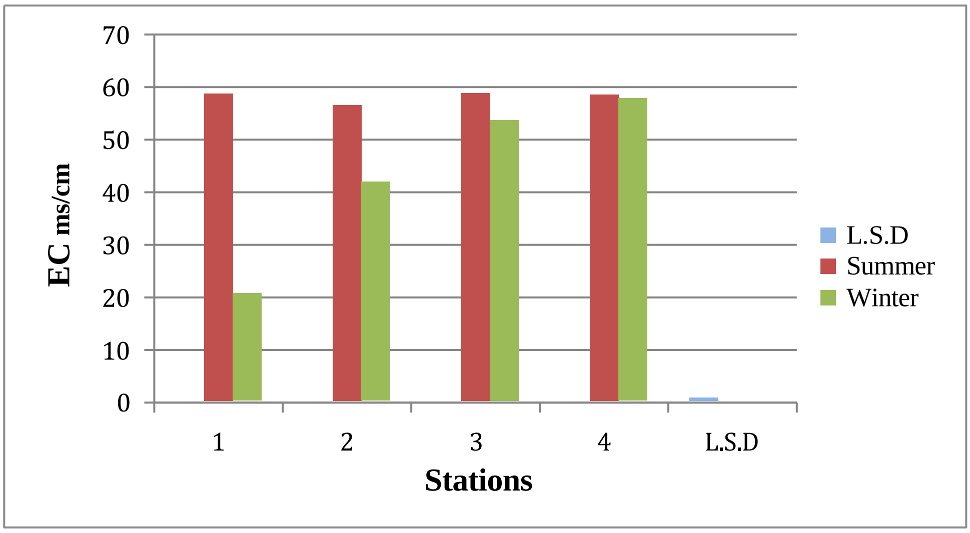


*Figure 5: Seasonal Variation in Conductivity Values at the Study Stations*

The recorded concentrations of Total Suspended Solids (TSS) during the summer were (360, 213, 285, 228), while winter values ranged between 76.3 and 362.6. It was observed that Station 1 decreased significantly in the winter, while stations 2and station 4 increased, which supports the hypothesis that in winter the measurement experienced freshwater dilution at the Naqah/Fao station (the first station), which is matched by the re-suspension of the flocs at the estuary and breakwater. This is consistent with the fact that flocs increase in areas with strong tidal currents and navigation or dredging activity, as reported in the description of the Khawr Abdullah stations near the navigational channels, which are considered to have high turbidity due to tidal currents(Abbas et al ,. 2020 ).Also, the increase in TSS raises the surface area available for adsorption, which explains its coincidence with the rise in concentrations of some heavy metals and with the increase in turbidity(Al- Abdulaziz et al., 2021).

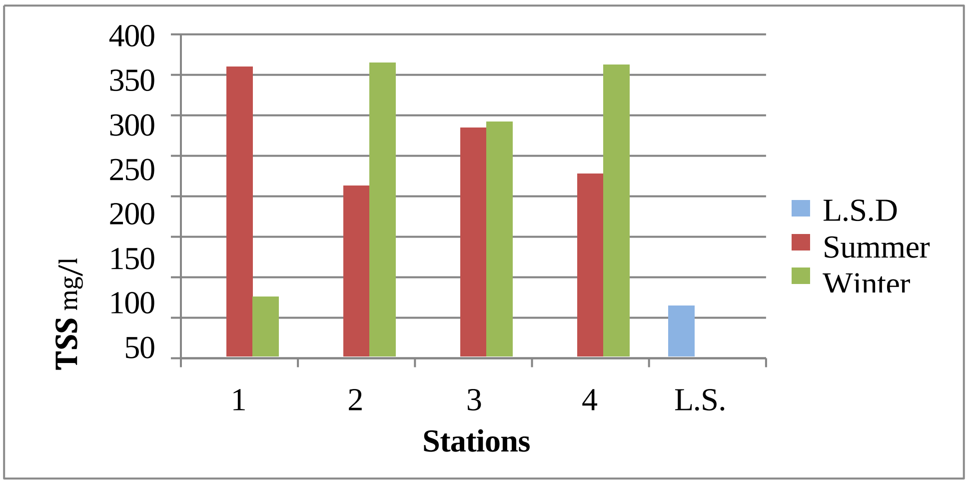


*Figure 6: Seasonal Variation in Total Suspended Solids Values at the Study Stations*

The results illustrated in Figure7 indicate that the highest dissolved oxygen concentrations were recorded during the winter season across the four monitoring stations, reaching 9.8, 10.4, 10.2, 9.2 mg/L respectively. Conversely, The lowest concentrations were observed during the summer season 8, 8.2, 8.9, 6.6 mg/L at the at the same stations, respectively

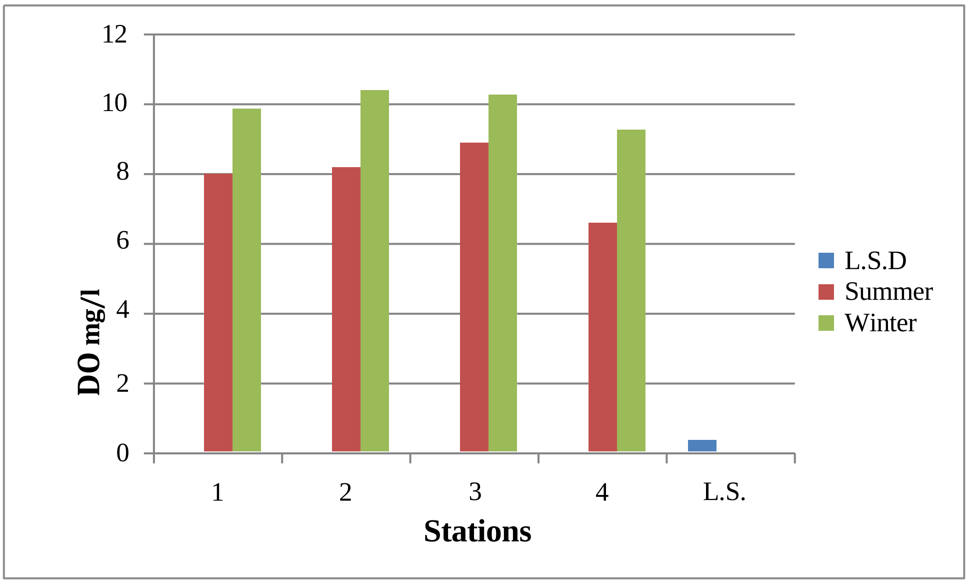


*Figure 7: Seasonal Variation in Dissolved Oxygen Values at the Study Stations*

The findings demonstrate that dissolved oxygen (DO) concentrations were consistently higher in winter than in summer across all stations. This is attributed to the decrease in temperatures and the increase in oxygen solubility in winter. In addition, there is increased mixing and natural aeration compared to summer (Al-Fartusi, 2018). Moreover, a study on Khor Al-Zubair indicated the sensitivity of dissolved oxygen to temperature as well as to the effects of untreated discharges. Large decreases could cause some stress on aquatic life, meaning that a DO level below 5 mg/L is considered stressful for fish, and below 3 mg/L threatens survival, linking these decreases to the effects resulting from untreated wastewater and high temperature (Hazza S Jassim, 2025).

The recorded pH values across all study stations remained consistently alkaline above 7. During the summer season the minimum and a maximum were7.56 and 7.89 at Stations 1 and 4, respectively. In the winter season, the recorded values were 7.77, 7.61, 7.79, and 7.68 at the four stations, respectively as shown in Figure 8 . Statistically, there were significant differences ($P < 0.05$) in pH values between seasons, and highly significant differences ($P < 0.01$) were found due to the interaction between seasons and stations, as well as between the stations themselves.

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.9, Issue 1, No.4. pp 84 - 105, 2026



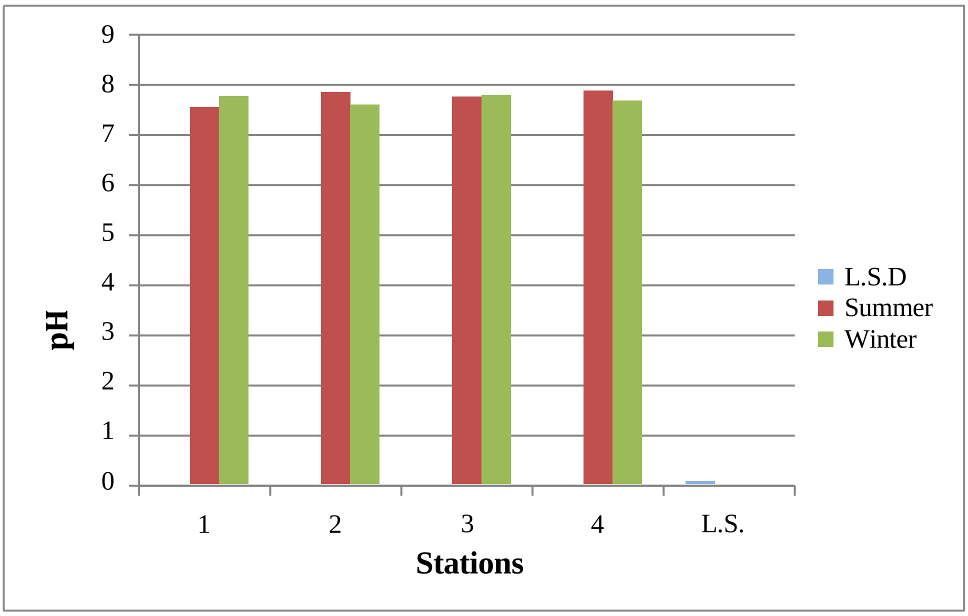


*Figure 8: Seasonal Variation in pH Values at the Study Stations*

pH values ranged between 7.56–7.89 in summer and 7.61–7.79 in winter, that is, within the neutral to slightly alkaline range, relatively stable despite changes in conductivity and salinity, which reflects a familiar behavior of the environments of northwest of the Gulf and the far south of Shatt al-Arab, where the bicarbonate (carbonate) system prevails as a buffering system that keeps pH within the range of 7.5 to 8.5 in most cases ((Hazza S Jassim, 2025; Fakher(b) et al., 2026). The slight differences in the data may be attributed to the balance of primary productivity (photosynthesis), which consumes $CO_2$ and raises pH, versus respiration and organic decomposition (which release $CO_2$ and lower pH, with the secondary effect of tidal mixing).

The concentrations of heavy metals measured in this study exhibit a robust correlation pattern with salinity, turbidity, and TSS, reflecting the role of sediments and plankton as primary reservoirs for metals within estuarine systems. The process of sediment resuspension also leads to an increase in the total fraction of metals in the water column. Local investigations have confirmed that metal concentrations vary seasonally and increase at some sites affected by shipping activity and near the estuary and coast(Abbas et al., 2021),( Hamdan, 2020)and (Al-Jaberi et al., 2016).

Figure 9 shows the total **zinc** concentrations ranged during the summer season (0.44, -0.524mg/l) and during the winter season (0.058-0.406mg/l) The results indicated that Zn increases in summer, especially at station 3, then remains moderate during winter with a significant decrease at station 1. This is explained by the fact that zinc is associated in estuarine and coastal environments with human sources such as (wastewater, surface runoff, port/paint activities), and it can also be partially transported with plankton. Since there are studies in Shatt al-Arab on heavy metals that indicated that some elements show a tendency to increase towards the estuary, due to wastewater and industrial and agricultural activities (Al-Khazaei et al., 2020). Therefore, the increase in zinc concentrations at station 3 during the summer can be linked to coastal and navigational activity as well as the resuspension or disturbance of sediments, while the significant decrease observed at station 1 during the winter corresponds to dilution caused by fresh water. Studies in the Iraqi coast have documented that there is a spatial variation of heavy metals and its relation to factors such as electrical conductivity and turbidity (Abbas et al., 2021).

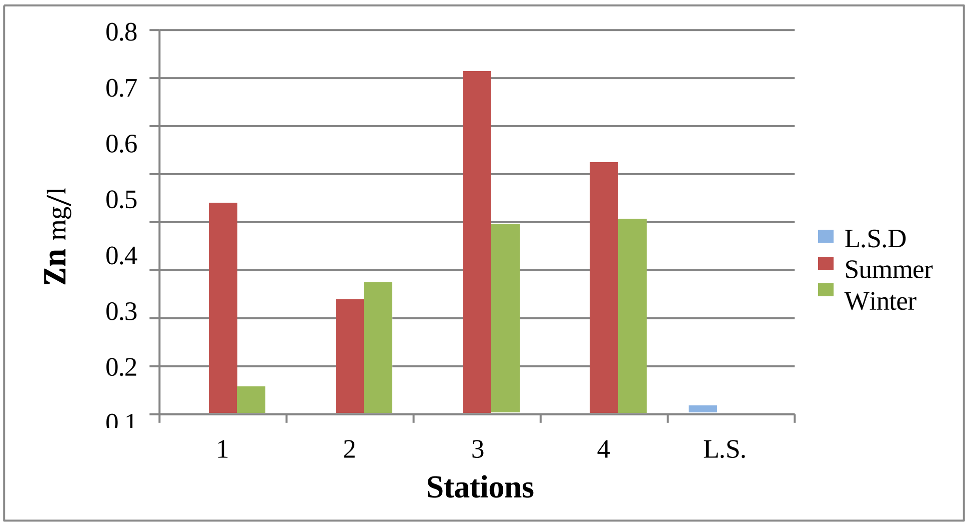


*Figure 9: Seasonal Variation in Zinc Concentrations at the Study Stations*

The illustrated results (Figure 10) show that the total manganese concentrations of the study stations were more during a summer (0.519, 0.22, 0.427, and 0.343 mg/l, respectively compared to the winter seasonal values 0.016, 0.058, 0.029, and 0.402 mg/l .A steep decrease in manganese concentrations is found in a winter at the stations 1 to 3, whereas the value is high Mn behavior is very sensitive to oxidation and reduction conditions, as an increase in oxygen usually helps precipitate Mn oxides, thus reducing dissolved values, whereas its concentrations can rise with resuspension or chemical changes in water near coastal facilities. Since DO is higher during winter at all stations, the decrease in dissolved Mn at stations 1–3 may reflect precipitation, while its continued high level at station 4 may be associated with strong resuspension due to high turbidity and TSS in winter.

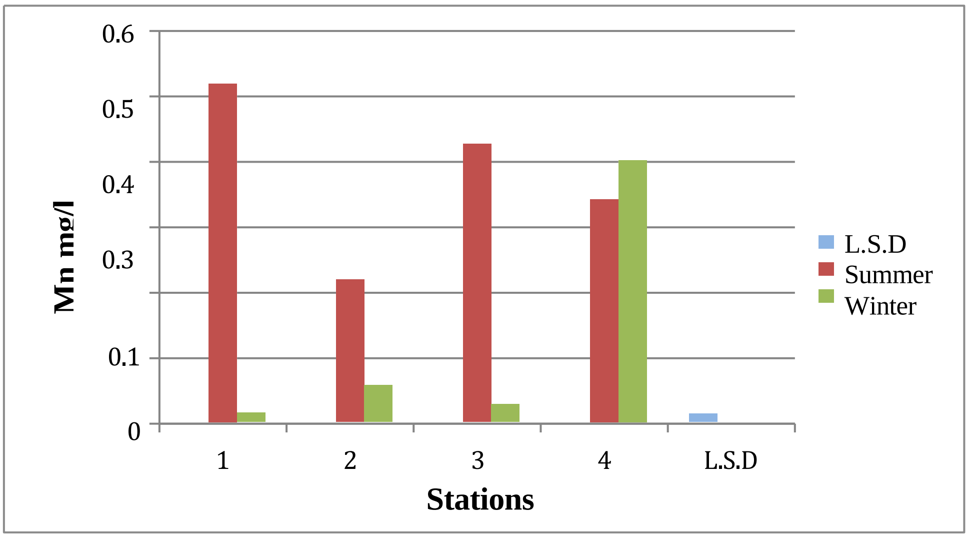


*Figure 10: Seasonal Variation in Manganese Concentrations at the Study Stations*

Figure 11 indicates that the overall copper content in the study stations in summer were 0.522 and 0.4, 0.549 and 0.441mg/l, respectively. On the other hand, the concentrations of winter were 0.075, 0.292, 0.441, and 0.535mg/l. The concentrations show that the large reduction of Cu over the winter at Station 1 is due to freshwater dilution whereas it rose over the winter at Station 4 (near the breakwater) relative to the summer, which may be due to some local effects associated with ship movement or partial resuspension and release of sediments under specific circumstances (turbidity and high TSS), over the winter at the same station (165 NTU and TSS=362.6). This is confirmed by studies of the Iraqi coast, which show that turbidity and TSS may increase at navigation channel and port stations as a result of tidal currents and ship movement. (Al abdulaziz et al., 2021).

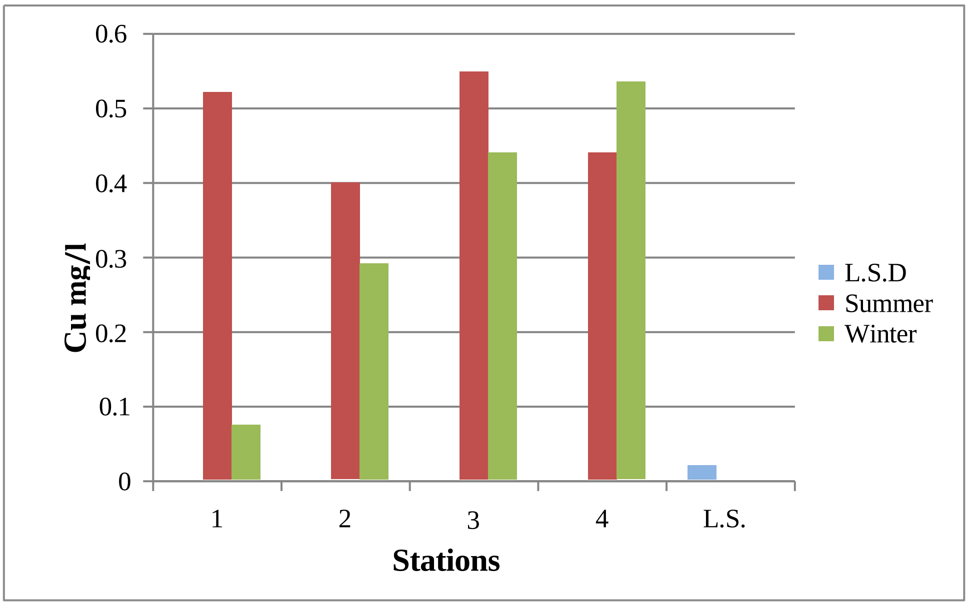


*Figure 11: Seasonal Variation in Copper Concentrations at the Study Stations*

The total **iron** concentrations across the study stations, as presented in Figure 12, were recorded at 4.637, 1.093, 3.853, and 1.701 mg/l during the summer. Conversely, the winter season showed a substantial increase in concentration levels, reaching 2.156, 6.688, 4.764, and 6.511 mg/l, respectively. The results showed significant increases in winter in the iron concentrations at stations (2 and 4) specifically, coinciding with turbidity and TSS, which are very high at stations 2 and 4. This is consistent with an Iraqi study which concluded that turbidity and TDS are positively correlated with Cd and Fe, and that increased turbidity acts as higher adsorption/carrying of iron on suspended particles, i.e., resuspension of sediments rich in iron oxides at the estuary and near the breakwater. Studies have also indicated that iron levels can rise by several mg/L in coastal environments near ports and maritime activity and vary seasonally (Al Abdulaziz et al., 2021; Hamdan, 2020). The estuary area is described as a clayey silt zone that is highly prone to disturbance (Al-Shammari, 2020). Additionally, a study (Reyes et al., 2025) indicated that elevated iron, especially in winter, is usually associated with sediment resuspension and dissolution of iron oxides in the estuarine environment. The study also indicates that iron and manganese are strongly associated with suspended sediments and redox conditions at river estuaries. This explains the relationship between high Fe and turbidity in the present study.

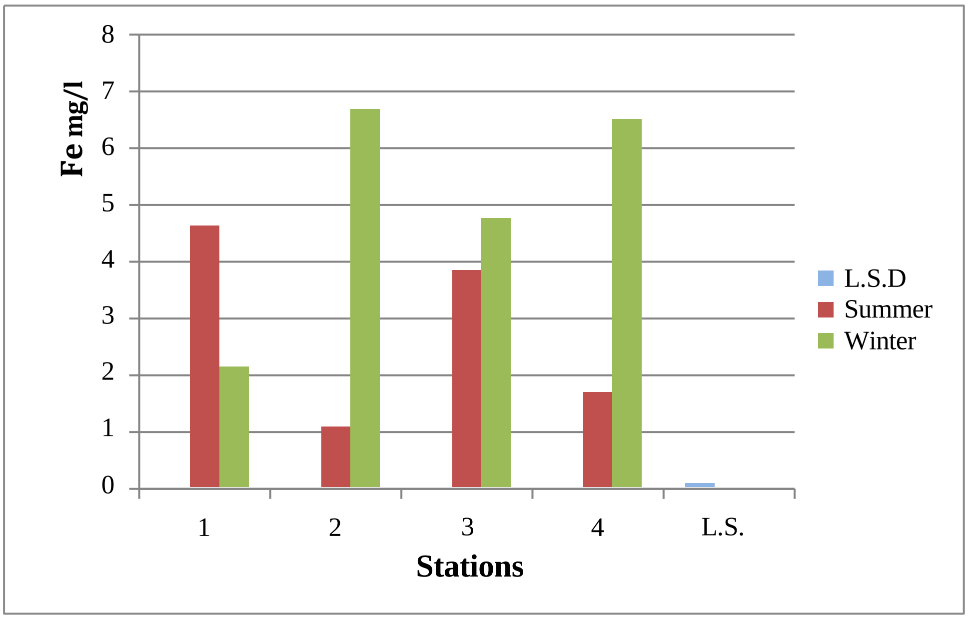


*Figure 12: Seasonal Variation in Iron Concentrations at the Study Stations*

Figure 13 was used to demonstrate that the total **lead** concentrations in the study stations were 4.385, 2.192, 3.245 and 3.07 mg/l in the summer. During the winter, the concentrations were changed to 1.315, 2.017, 2.456 and 3.245 mg/l respectively. The findings indicated that at the stations 1 and 3 the lead concentrations were relatively higher in the summer and in the winter at station 4, the lead levels were still high. Given the fact that Pb is an element that is deemed toxic in even low levels besides being bioaccumulative, sources of Pb in estuarine and coastal environments are usually attributed to urban, maritime, industrial sources, municipal discharge, and aerial deposition (Al- Khuzaie et al., 2020) and (Qasim S Ali, 2022). There is also a study on the Iraqi coast that showed a positive relationship between Pb, pH, and Zn (Al Abdulaziz et al., 2021). One of the reasons for the high concentrations of lead may be attributed to the large amount of lead used in fishing nets continuously over the past years in the study area, as it is considered an area with constant movement of fishing boats from Al-Naqaa (Al-Faw) to the Iraqi coastal waters. There are also thousands of abandoned fishing nets settled on the bottom, which later decompose under certain conditions and become trapped with the sediments. In another study (Olowojuni et al., 2025) on lead pollution in coastal waters, it is mainly associated with human activities represented by waste discharge, shipping, industrial waste disposal, and petroleum sources.

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.9, Issue 1, No.4. pp 84 - 105, 2026



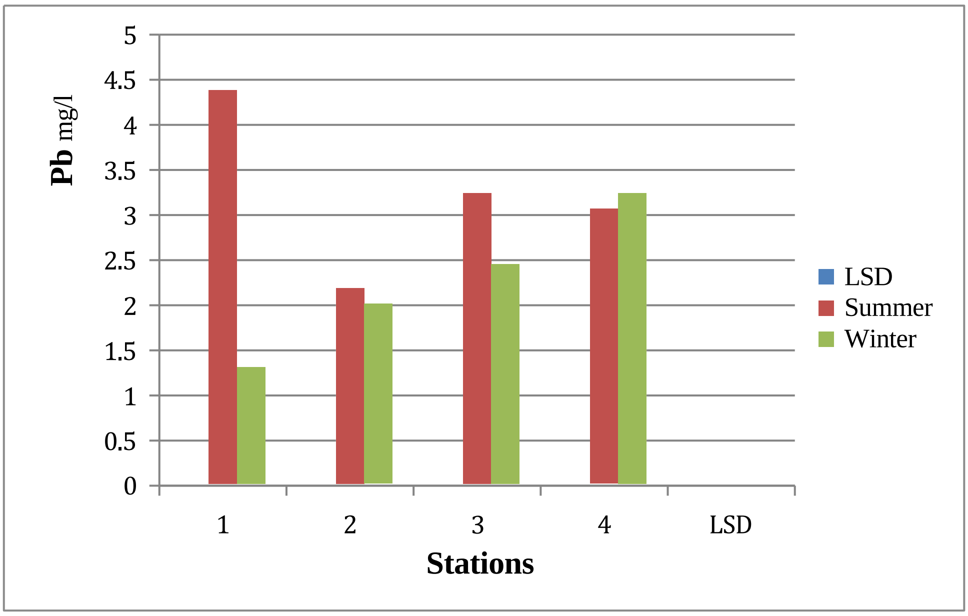


*Figure 13: Seasonal Variation in Lead Concentrations at the Study Stations*

As Figure 14 noted, the overall levels of **cadmium** were found to be 0.84, 0.4, 0.64 and 0.58mg/l in the summer. There was a radical decrease during the winter season, as concentration levels reduced to 0.073, 0.19, 0.3, and 0.39 mg/l. Cadmium concentration tends to decrease in the winter due to freshwater dilution, especially at station 1 compared to the summer, with values remaining relatively higher towards the stations closer to the marine coastal influence. Since Cd is considered a non-essential element and highly toxic, its sources are mostly from industrial, municipal, and agricultural discharge. A study in the Shatt Al-Arab indicated that Cd increases downstream in the river, with the highest concentration at Al-Faw, attributing the increase to discharge and industrial and agricultural activities (Al-Khuzaie et al., 2020). The association of high Cd with increased turbidity and TDS is documented in studies on the Iraqi coast, where Cd concentrations rise with increased turbidity, TDS, and Fe due to adsorption on suspended particles (Al abdulaziz et al., 2021). Another study (Ali et al., 2025) indicated that cadmium usually appears at higher concentrations during the dry season due to reduced dilution and increased evaporation.

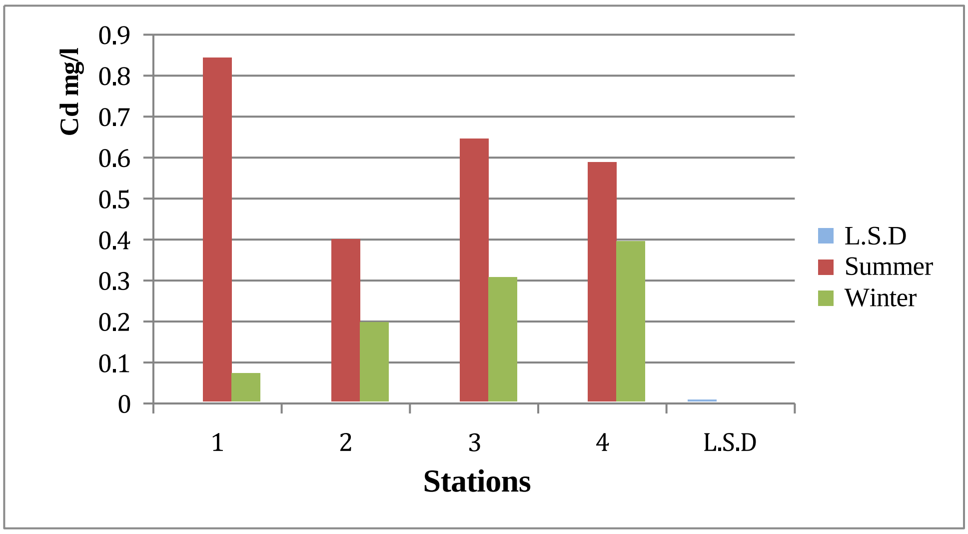


*Figure 14: Seasonal Variation in Cadmium Concentrations at the Study Stations*

As illustrated in Figure 15, the total nickel concentrations across the study stations during the summer were recorded at 1.9, 0.44, 1.26, and 1.06 mg/l, respectively. In the winter, these concentrations shifted to 1.2, 2.03, 2.52, and 2.99 mg/l, showing a notable increase in the majority of the stations. The nickel element exhibits opposite behavior during the winter, being much higher at stations 2–4. This can be attributed to the increase in winter runoff, which may carry Ni from the land and waste into the estuary area, as well as the resuspension of sediments during the winter due to increased turbidity and TSS, which may release nickel or carry it in suspended form. It could also be due to the presence of nearby industrial and maritime sources in the study area such as the dock, ports, and dredging, whose effect might be more evident in the winter with hydrodynamic changes. Studies on the Shatt al-Arab and the Iraqi coast have also indicated that sources of heavy metals include industrial and oil discharge, municipal, maritime, and atmospheric deposition (Al Khuzaie et al., 2020) .

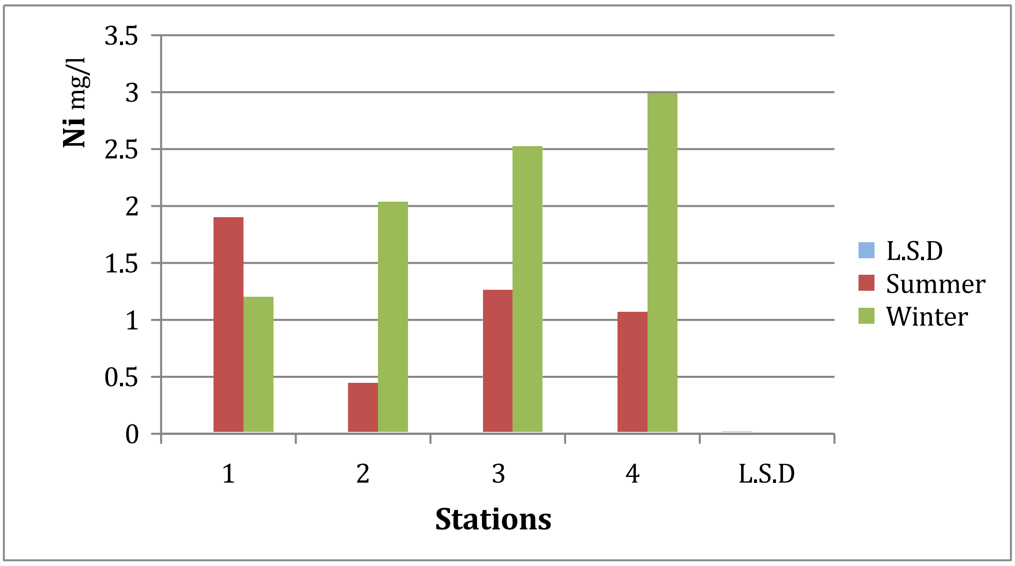


*Figure 15: Seasonal Variation in Nickel Concentrations at the Study Stations*

The physicochemical analysis of the current study reveals significant seasonal and spatial variations compared to previous literature as shown in table 2. While water temperature 13.3–35.9 C° and pH values 7.56–7.89 were consistent with the ranges reported by Fakher et al. (2026) and Hazza S Jassim (2025), the dissolved oxygen (DO) levels 8.0–10.4 mg/l were notably higher than those found by (Jassim S Al-Amiri (2023), indicating better aeration and lower organic loading. Salinity and EC values remained within the moderate- to-high thresholds documented by Abbas et al. (2020), yet they were significantly lower than the hyper saline peaks reported by Hazza S Jassim (2025). Most notably, the current study recorded exceptional increases in turbidity 396.6 NTU and TSS 364.6 mg/l, substantially surpassing the findings of (Siwan 2021) and (Fakher et al. 2026). This unprecedented rise in suspended matter suggests intensified anthropogenic activities, localized dredging, or increased sediment runoff compared to previous years.

**Table 2: Previous Studies on the Physical and Chemical Properties of Water and Their Comparison with the Current Study**

| DO mg/l | EC ms/cm | TSS mg/l | Tur (NTU) | Sali ppt | pH | WT C° | Min and max value | Studies |
|---|---|---|---|---|---|---|---|---|
| 4.7 | 11.9 | - | - | - | 7.9 | - | Min | (Jassim & Al-Amiri, 2023) |
| 11.1 | 29.7 | - | - | - | 8.4 | - | Mxa | |
| - | 45.7 | - | 0.64 | - | 7.6 | 14 | Min | (Al abdulaziz et al., 2021) |
| - | 77.1 | - | 81 | - | 8.5 | 34 | Mxa | |
| 5.4 | 45.7 | 0.04 | 0.64 | 36.2 | 7.7 | 14 | Min | (Abbas et al ,. 2020 ) |
| 14 | 77.1 | 0.34 | 81 | 49.3 | 8.5 | 34 | Mxa | |
| 2.5 | - | - | - | 41 | 8.2 | 15.1 | Min | (Hazza & Jassim, 2025) |
| 7.5 | - | - | - | 50 | 8.6 | 33.5 | Mxa | |
| 4.4 | 5.98 | - | 36.9 | - | 7.8 | 20 | Min | (Siwan, 2021) |
| 7.2 | 8.21 | - | 92.7 | - | 7.93 | 31 | Mxa | |
| 5 | 5.01 | - | 0.11 | 2.49 | 7.12 | 16.8 | Min | (Fakher et al., 2026) |
| 13 | 61.8 | - | 59.26 | 39 | 8.04 | 34.8 | Mxa | |
| 8 | 20.8 | 76.3 | 15.73 | 11.8 | 7.56 | 13.3 | Min | The current study |
| 10.4 | 58.9 | 364.6 | 396.6 | 36.1 | 7.89 | 35.9 | Mxa | |

In Table 3 the heavy metal analysis in the current study reveals concentrations that frequently exceed both regional and international safety limits, particularly for Lead and Cadmium. While Iron levels (1.093–6.688 mg/l) and Manganese levels (0.0167–0.519 mg/l showed consistency with the findings of (Al-Abdulaziz et al. 2021) and (Jassim S Al-Amiri 2023), they significantly surpassed the Iraqi River Systems and WHO standards 0.3 mg/l for Fe and 0.1 mg/l for Mn. Most notably, the maximum concentrations of Lead 4.385 mg/l and Cadmium 0.843 mg/l recorded in this study are alarmingly higher than the values reported by (Al-Khuzaie et al. 2020) and far exceed the permissible limits set by WHO 0.01 mg/l for Pb and 0.003 mg/l for Cd. Nickel and Copper also displayed elevated levels compared to previous years, reflecting a progressive trend of heavy metal accumulation. These findings suggest a significant degradation in water quality, likely driven by intensified industrial discharge and anthropogenic activities that have escalated since the studies of 2020–2024.

**Table 3: Permissible Concentrations Worldwide and in Iraq for Trace Metals (Mg/L) in Water, Compared with the Current Study and Other Studies**

| Ni ppm | Cu ppm | Mn ppm | Zn ppm | Pb ppm | Cd ppm | Fe ppm | Min and max value | Studies |
|---|---|---|---|---|---|---|---|---|
| - | 2 | 0.4 | 3 | 0.01 | 0 | 0.05 | - | WHO (2004 S2011) |
| - | 0.2 | 0.2 | 2 | 5 | 0.01 | 5 | - | Ayers and Westcot (1985) |
| - | 0.05 | 0.1 | 0.5 | 0.05 | 0.01 | 0.3 | - | Iraqi systems for rivers |
| - | - | - | 0.01 | 0.555 | 0.061 | 0.472 | Min | (Al abdulaziz et al., 2021) |
| - | - | - | 0.635 | 0.666 | 0.899 | 9.843 | Mxa | |
| - | - | 0.0331 | 0.066 | 0.063 | 0.02 | 1.1973 | Min | (Jassim & Al-Amiri, 2023) |
| - | - | 0.1638 | 0.4518 | 0.3889 | 0.1063 | 8.776 | Mxa | |
| - | 0.1 | 0.23 | 0.20 | 0.14 | 0.01 | 0.27 | Min | (Al-Khuzaie et al., 2020) |
| | 0.29 | 0.35 | 0.31 | 0.22 | 0.03 | 0.60 | Mxa | |
| - | - | 0.1149 | 0.1028 | 0.0922 | 0.0418 | 2.44 | Min | (Jassim et al., 2024) |
| - | - | 0.1397 | 0.3276 | 0.301 | 0.0988 | 5.237 | Mxa | |
| 0.446 | 0.075 | 0.0167 | 0.058 | 1.315 | 0.073 | 1.093 | Min | The current study |
| 2.99 | 0.549 | 0.519 | 0.715 | 4.385 | 0.843 | 6.688 | Mxa | |

## Statistical Analysis

Statistical analysis showed the presence of a highly significant interaction effect ($P < 0.01$) between season and station, reflecting the influence of tidal- river mixing processes, variations in discharge, and evaporation on the variability of physical, chemical, and heavy metal characteristics. A positive correlation was also observed between trace metal levels and some physical and chemical factors. There is a positive relationship between (turbidity and TSS) and certain trace elements. Additionally, these parameters increase linearly with one another. From this, we conclude that the increase in turbidity is directly associated with a higher level of trace metals on the surface of suspended particles present in coastal marine waters.

## Conclusion

The quality of water in the rivers of Iraq, in general, faces deterioration over time. The levels of chemical and physical parameters continuously change throughout the year due to their connection with human sources as well as weather conditions. In this study, changes in water temperature, conductivity, salinity, and pH were determined in the field, along with the concentrations of major water pollutants. The highest changes in water temperature values between the summer and winter seasons primarily depended on changes in air temperature, which was highest during the summer due to the long daylight period and lowest during the winter due to the short daylight period. The levels of turbidity and total suspended solids increased at stations (1, 2, 3) at the midstream, the estuary, and near the breakwater of Al-Faw Grand Port towards the north from the western Arabian Gulf. This increase contributes to the suspension of sediments, which aligns with the results obtained for the Shatt al-Arab River**.** Due to the reduction of water in the city of Al-Faw and the gradient towards the estuary area as a result of the discharge of fresh water after the opening of the Karun River due to Iranian floods, as well as the impact of the Tigris and Euphrates rivers discharge during the winter, this led to a decrease in salinity, conductivity, and some trace elements concentrations. The effect of tides from the Arabian Gulf also has a significant impact on the changes. In conclusion, this study serves as a database that includes many different parameters and changes that are subject to variation in Iraqi coastal waters.

**Recommendations**

According to the outcomes of the research, the following is suggested:

- Regular and constant assessment of water quality in the study area.
- Minimize the pollution sources, particularly the agricultural and industrial discharges.
- Enhance the control of water resources in such a manner that would allow reducing the role of salinity.
- Continuous future study needs to be done on long term basis in order to understand environmental changes better.

## REFERENCES

Abbas, M. F., Al-Mayah, S. H., & Khalaf, T. A. (2020). Primary productivity of the Iraqi coastal waters and some affecting environmental factors. International Journal of Biosciences, 17(2), 314–324.

Al-Abdulaziz, B. A., Abbas, M. F., & Al-Imarah, F. J. (2021). Changes in some heavy elements concentrations and their relationship with some environmental factors in the Iraqi coastal waters. Basrah Journal of Science, 39(3), 538–555.

Al-Badran, B. (1995). Lithofacies of recent sediments of Khor Abdullah and Shatt Al-Arab delta, Northwest Arabian Gulf. Iraqi Journal of Science, 36(4), 1133–1147.

Al-Daraji, F. K., Ndewi, D. R., & Al-Shammari, H. M. (2024). *Modeling and analysis of land surface temperature variations in Basrah Governorate, Iraq, using remote sensing data and geomatics techniques*. In A. J. Obaid et al. (Eds.), *Advanced studies on environmental sustainability*. Springer. https://doi.org/10.1007/978-3-031-57054-4_7

Al-Fartusi, A. J. M. (2018). The low discharge simulation of the Shatt Al-Arab River and its influence on water quality. Mesopotamian Journal of Marine Science, 33(1), 1–18.

Ali, A. W., Al-Ankush, M. A. T., & Hussain, N. A. (2025). Evaluating the levels of heavy metals pollution in the water and sediments of Khor Al-Zubair, Southern Iraq, using heavy metal pollution index (HPI). Egyptian Journal of Aquatic Biology & Fisheries, 29(4), 245–260.

Al-Jaberi, M. H., Al-Dabbas, M. A., & Al-Khafaji, R. (2016). Assessment of heavy metals contamination and sediment quality in Shatt Al-Arab River, southern Iraq. Iraqi Geological Journal, 49(1), 88–97. https://doi.org/10.46717/igj.39-49.1.7Ms-2016-06-29

Al-Khuzaie, D. K. K., Hassan, W. F., Imran, R. A., & Abdulnabi, Z. A. (2020). Water quality of Shatt Al-Arab River in Basrah, Iraq: Heavy and trace metal concentration. Pollution Research, 39(2), 231–236.

Al-Nafisi, R. S. (2009). Positive impact of mangrove plantation on Kuwait coastal environment. European Journal of Scientific Research, 26(4), 510–521.

Al-Shamary, A. C., Yousif, U. H., & Younis, K. H. (2020). Study of some ecological characteristics of Iraqi marine waters, southern Iraq. Marsh Bulletin, 15(1), 19–30.

Al-Shammari, A. J. J. (2020). Assessment of the Shatt Al-Arab estuary environment and Iraqi marine waters using the Estuarine Biological Integrity Index (EBI) (Doctoral dissertation). University of Basrah, Basrah, Iraq.

Al-Shawi, A. J. (2010). Ecological study and classification of plankton in Khor Al-Zubair with estimation of total oil hydrocarbons levels (Doctoral dissertation). University of Basrah, Basrah, Iraq.

Al-Taei, S. A., Abdullah, S. S., & Al-Mahdi, A. (2019). Simulation of salinity intrusion into the Shatt Al-Arab River, south of Iraq. Journal of King Abdulaziz University: Marine Sciences, 29(1), 91–103. https://doi.org/10.4197/Mar.29-1.6

Al-Zlemat, N. S. A. (2019). Assessment of physical and chemical characteristics of water quality in Iraqi marine environment (Master's thesis). University of Basrah, Basrah, Iraq.

American Public Health Association (APHA), American Water Works Association (AWWA), & Water Environment Federation (WEF). (2023). *Standard methods for the examination of water and wastewater* (24th ed.). American Public Health Association.

Castro, P., & Huber, M. (2003). Marine biology (4th ed.). McGraw-Hill.

Chapman, D. (Ed.). (1996). *Water quality assessments: A guide to the use of biota, sediments and water in environmental monitoring* (2nd ed.). UNESCO/WHO/UNEP.

Environmental Protection Agency (EPA). (2004). National coastal condition report II: Classification framework for coastal systems. U.S. Environmental Protection Agency, Washington, DC.

Fakher, N. H., Al-Shawi, I. J. M., & Abdulnabi, Z. A. (2026). Assessment of selected physical and chemical water quality indicators in the Shatt al-Arab River and the northwest Arabian Gulf, Iraq (2024–2025). Egyptian Journal of Aquatic Biology & Fisheries, 30(1), 1793–1809.

Ghani, A. A. (1988). Hydrochemical characteristics of Shatt Al-Arab River and southern Iraqi waters. Journal of Mesopotamian Science, 3(1), 103–104.

Hamdan, A. N. A. (2020). Assessment of heavy metals pollution in the Shatt Al-Arab River, Basra-Iraq. AIP Conference Proceedings, 2213, 020037. https://doi.org/10.1063/5.0000300

Hartmann, M., Lange, H., Seibold, E., & Walger, E. (1971). Surface sediments in the Persian Gulf and Gulf of Oman. Marine Geology, 11(3), 141–157.

Hazza, M. A., & Jassim, A. K. (2025). Evaluation of the water quality of the northern part of Khor Al-Zubair lagoon using Index Biological Integrity of Phytoplankton (P-IBI). University of Thi-Qar Journal of Agricultural Research, 14(1), 252–263. https://doi.org/10.54174/utjagr.v13i1.323

Hussain, N. A., Ali, T. S., & Saud, K. D. (1989). Seasonal fluctuations of fish assemblage in Shatt Al-Arab River, southern Iraq. Marine Mesopotamica, 4(2), 123–138.

Hussain, N. A., Najjar, H. H., & Mohamed, A. R. M. (1991). Shatt Al-Arab: Basic scientific studies. Marine Science Center, University of Basrah, Basrah, Iraq.

Jawad, L. A., Ziyadi, M. S. F., Naslund, J., Pohl, T., & Al-Mukhtar, M. A. (2018). Checklist of fishes in Iraqi coral reef waters, Arabian Gulf. Zootaxa, 4425(1), 1–30.

Keithan, E. D., & Lowe, R. L. (1985). Primary productivity in streams. Hydrobiologia, 123, 59–67.

Khalaf, K. K., Al-Asadi, M. A. W., & Al-Mahmoud, H. K. H. (2021). The variation of the qualitative characteristics of surface water in Basra Governorate for the period (2018–2019). Basra Journal of Arts, 98(1), 215–246.

Lateef, Z. Q., Al-Madhhachi, A.-S. T., & Sachit, D. E. (2020). Evaluation of water quality parameters in Shatt Al-Arab, southern Iraq, using spatial analysis. Hydrology, 7(4), 79. https://doi.org/10.3390/hydrology7040079

Mohamed, A. R. M., Ali, T. S., & Hussain, N. A. (2002). Stock condition of tonguesole fish (Cynoglossus spp.) in the northwestern Arabian Gulf. Iraqi Journal of Aquaculture, 1(1), 45–58.

Olowojuni, O., Olaifa, F. E., Oyebola, O. O., Ayotunde, D. T., Kelani, A. Z., & Olusola, S. E. (2025). Seasonal and spatial variations in water quality, heavy metal concentration in water, sediment and bioaccumulation in Pseudotolithus species from the Gulf of Guinea, Ondo State, Nigeria. Environmental Sciences Europe, 37, 181. https://doi.org/10.1186/s12302-025-01221-7

Purser, B. H., & Seibold, E. (1973). Environmental factors influencing sedimentation in the Arabian Gulf. Sedimentology, 20(1), 121–138.

Qasim, A. M., & Ali, T. S. (2022). Spatiotemporal analysis on shipwrecks in Shatt Al-Arab River and Iraqi marine waters northwest Arabian Gulf. Basrah Journal of Agricultural Sciences, 35(1), 212–228.

Reyes-Márquez, A., Barrera-Huertas, H. A., Sedeño-Díaz, J. E., Morales-Acuña, E., Aguíñiga-García, S., Cervantes-Duarte, R., & López-López, E. (2025). Heavy metal pollution in water and seston in a subtropical coastal lagoon of the Gulf of Mexico: Hydrometeorological and anthropic influence. Water, 17(13), 1929. https://doi.org/10.3390/w17131929

United Nations Environment Programme (UNEP). (2008). *Water quality for ecosystem and human health* (2nd ed.). UNEP Global Environment Monitoring System (GEMS)/Water Programme.

United States Environmental Protection Agency (EPA). (2019). National coastal condition assessment 2015: A collaborative survey of the nation’s coastal waters. U.S. Environmental Protection Agency, Washington, DC.