Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 691 – 701 (2025)
www.ejabf.journals.ekb.eg

# Temporal and Spatial Changes in Organic Pollution Levels Using the Organic Pollution Index (OPI) in Khor Al-Zubair, Southern Iraq

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## ARTICLE INFO

**Article History:**
Received: May 28, 2025
Accepted: July 5, 2025
Online: July 13, 2025

**Keywords**:
Khour Al-Zubair,
Organic pollution index,
Water pollution

## ABSTRACT

The organic pollution index (OPI) was employed to assess the temporal and spatial variations of organic pollutants in Khor Al-Zubair, southern Iraq. Four key parameters ($BOD_5$, $NO_3$, $PO_4$, and $NH_4$) were analyzed from water samples collected monthly between January and December 2024 at three monitoring stations. The annual OPI values showed a descending trend, with the highest value recorded at Station 1 (194.42), followed by Station 2 (157.54), and the lowest value at Station 3 (151.54). Spatial and temporal OPI values fluctuated significantly, ranging from a peak of 324.27 at Station 1 in January (classified as very poor) to a minimum of 26.58 at Station 3 in April (classified as good). Station 1 consistently exhibited the highest OPI values alongside elevated concentrations of $BOD_5$, $NO_3$, $PO_4$, and $NH_4$ throughout most months. The study confirmed the presence of serious organic pollution in the water, particularly at Station 1. This is primarily due to the discharge of large quantities of untreated sewage from the Hamdan Wastewater Treatment Plant and the Shatt al-Basra Canal into the Khor al-Zubair waterway, in addition to numerous human activities.

## INTRODUCTION

Marine and river waters are under constant threat from the discharge of untreated sewage and industrial wastewater. These pollutants contain organic and toxic materials that impact aquatic life, causing economic losses by affecting organisms and fish populations, leading to their migration or death **(Yaseen *et al*., 2024)**. The uncontrolled discharge of sewage into waterways without prior treatment is one of the major causes of water pollution. This issue is exacerbated by the absence of strict laws and oversight, allowing these waters to carry pollutants, toxins, pathogenic bacteria, and nutrients that harm the environment **(Aldoghachi, 2022; Aldoghachi *et al.*, 2025)**.

Sewage discharge leads to oxygen depletion in water bodies due to the large quantities of non-biodegradable organic materials it contains. This situation necessitates efficient and scientifically managed wastewater treatment to minimize environmental harm **(Supardiono *et al.*, 2023)**. Additionally, the excessive use of nitrogen-based fertilizers in agriculture contributes significantly to aquatic pollution through nitrate and phosphate leaching, elevated nutrient levels, and soil acidification. In many cases, the agricultural sector has become the primary source of nutrient pollution **(Pericherla *et al.*, 2020)**.

There are various sources of organic pollution. **(Boluda *et al.*, 2002)**, after applying the Organic Pollution Index using a set of water pollution factors on the Mediterranean coast of Spain, identified three primary sources of organic pollution: sewage from residential areas, heavy metals, and agricultural runoff resulting from the use of organic and chemical fertilizers. An excess of organic matter beyond natural limits leads to increased biological metabolism and decomposition due to heightened bacterial activity. This process results in eutrophication **(Rheuban *et al*., 2019)**, a phenomenon characterized by excessive phytoplankton blooms that block sunlight, reduce oxygen exchange, cause foul odors and decay, and eventually lead to the death of aquatic organisms **(Okoye *et al.*, 2023)**.

Iraq borders the northwestern edge of the Arabian Gulf with a 50-mile coastline. Khor Al-Zubair, an extension of the Arabian Gulf, is part of Iraq's marine waters and is known as one of the most biologically productive areas, providing a favorable environment for the reproduction and feeding of various fish species **(Yaseen *et al.*., 2018; Al-Ramadan, 1986)**. Strategically located in southern Iraq, Khor Al-Zubair is connected to the Shatt Al-Basra Canal in the north and the Arabian Gulf in the south. Its water quality is significantly influenced by tidal currents from the Gulf **(Ali & Hussain, 1990)**. These currents distribute pollutants from various sources, including sewage, heavy metals, port activities, agriculture, and the transportation of oil and petroleum products, all of which contribute to the region's environmental pollution **(Al-Saad, 2007)**.

Despite the significance of organic pollution, the Khor Al-Zubair region has received minimal research attention. Most existing studies are outdated and did not utilize the Organic Pollution Index, focusing instead on general environmental conditions. These include the studies by **Ali and Hussain (1990)** and **Al-Saad and Almaliki (2008)**. The current study aims to identify both temporal and spatial changes in organic pollutant levels through the application of the Organic Pollution Index, while also determining the most influential factors affecting the index's values.

## MATERIALS AND METHODS

### Study area

The Khor Al-Zubair region is an extension of the Arabian Gulf, stretching northwestward into lower Mesopotamia. Historically connected to the Hammar Marsh, this connection has transformed its characteristics from a purely marine system into an estuarine-like environment. Khor Al-Zubair spans approximately 32 kilometers in length, with an average depth ranging between 14 -18 meters **(Al-Ramadan, 1986)**. To the north, the area is bounded by the Al-Zubair Bridge and the Shatt Al-Basra Regulator. The

Hamdan Station, located north of the first monitoring station, is a notable source of sewage discharge. On the eastern side, there is a station designated for small and medium-sized fishing boats. Along the western shore of the creek, several industrial facilities operate, including petrochemical plants, iron and steel factories, and fertilizer production units. A key feature of the region is its western boundary, which hosts the Khor Al-Zubair ports. These ports handle thousands of large vessels involved in the export and import of petroleum products. Additionally, the nearby port of Umm Qasr and the adjacent free zone accommodate ships carrying various goods, alongside a dedicated gas export terminal.

## Study stations

Three sampling stations were selected in Khor Al-Zubair based on their geographic coordinates, as detailed in Table (1) and showed in Fig. (1). Samples were collected monthly over a full year, from January to December 2024, at low tide from each of the three stations.

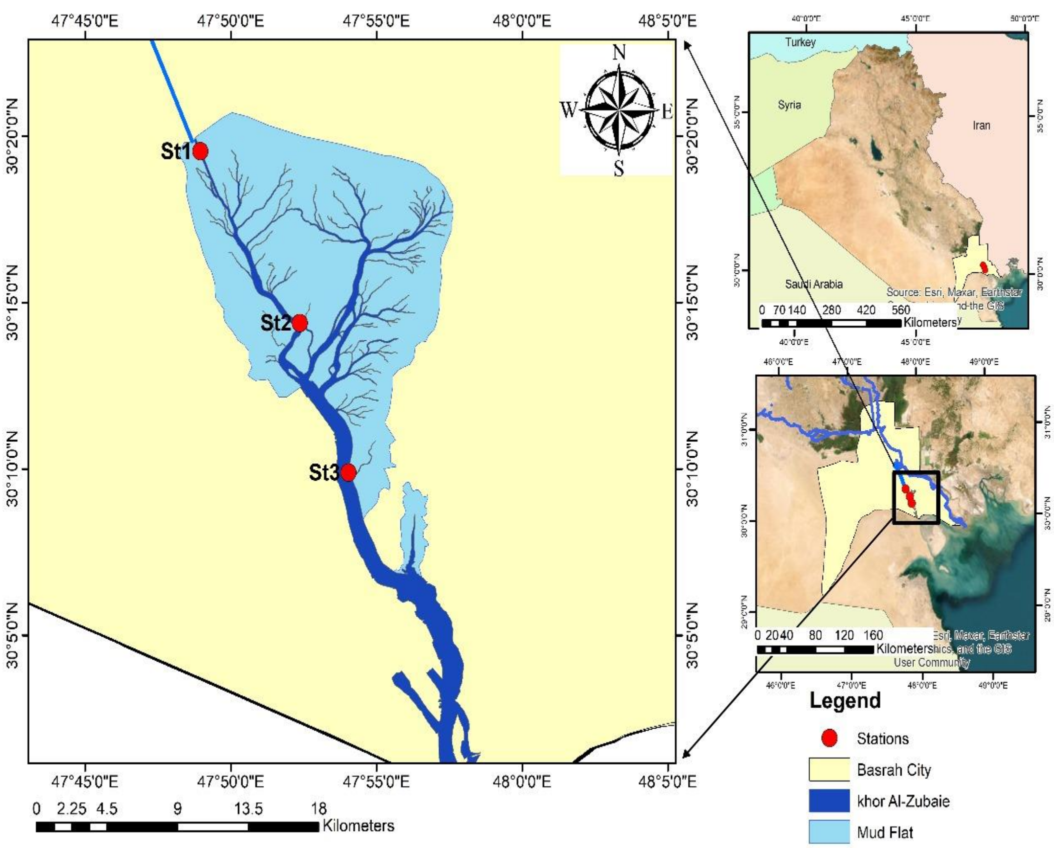


**Fig. 1.** Map of study and sample collection stations

**Table 1.** Coordinates of the study stations

| Station | Latitude | Longitude |
|---|---|---|
| St1 | 30°19'33.00''N | 47°48'56.90''E |
| St2 | 30°14'23.30''N | 47°52'21.90''E |
| St3 | 30°9'53.80''N | 47°54'1.80''E |

Water samples were collected using 500ml plastic bottles, which were filled to capacity and immediately stored in refrigerated boxes to preserve sample integrity during transport to the laboratory. Additionally, opaque Winkler bottles with a capacity of 225–250ml were employed for on-site measurement of Biological Oxygen Demand (BOD). Dissolved oxygen (DO) was measured in the field as an initial parameter. Subsequently, BOD was determined by incubating the samples for five days, after which the oxygen levels were re-measured using an American-made YSI 556 dissolved oxygen meter.

**Organic pollution index (OPI)**

After determining the time period for the study—covering the four semesters of 2024—and selecting the variables involved in calculating the value of the guide and the standard criteria (Table 3), the final results of the guide were compared with those in Table (2). To enhance clarity and make the outcomes more understandable and acceptable to decision-makers and administrators, the equation was adjusted to a percentage scale, as indicated in **Boluda *et al.* (2002)** as follows:

$$OPI = (\sum Ci / Cmi) / n \times 10$$

Ci: The experimental value of each factor.
Cmi: Maximum allowed.
n: Number of variables.

**Table 2.** The values of the organic pollution index (OPI)

| Evidence scores | Organic contamination levels | Evidence value |
|---|---|---|
| 1 | Very good | 9≤ |
| 2 | Good | 29-10 |
| 3 | Average | 39-30 |
| 4 | Weak | 49-40 |
| 5 | Deteriorating | 59-50 |
| 6 | Poor | 69-60 |
| 7 | Very poor | 70≥ |

### Selection of variables

Four variables were selected for calculating the organic pollution index: biological oxygen demand ($BOD_5$) Mg. $l^{-1}$, nitrate ($NO_3^-$) µg. $l^{-1}$, ammonium ($NH_4^+$) Mg. $l^{-1}$, and phosphate ions ($PO_4^{-3}$) µg. $l^{-1}$. The criteria and standard specifications for these variables, used in the index calculation, are presented in Table (3). Nitrate concentration was measured following the method described by **APHA (2005)**. Phosphate was measured using the method outlined by **Strickland and Parsons (1972)**, and ammonium was determined according to **APHA (2005)** protocol, employing a Kjeldahl apparatus.

**Table 3.** Maximum permissible limits for organic pollution index variables

| **Variables** | **Iraqi systems for rivers maintain (2011)** | **US-EPA (2012)** | **WHO (2004,2001)** | **Units** |
|---|---|---|---|---|
| $BOD_5$ | <3 | - | 5 | mg/L |
| $NO_3$ | 15000 | 10000 | 50000 | $mg/m^3$ |
| $PO_4$ | 400 | 40** | - | $mg/m^3$ |
| $NH_4$ | 1000 | 30000 | NG * | $mg/m^3$ |

### Statistical analysis

The Statistical Package for Social Science (SPSS) and Principal Component Analysis (PCA) software (Canoco ver. 4.6) were used to analyze the data of this study.

## RESULTS AND DISCUSSION

The levels of organic pollution in the waters of Khor Al-Zubair were evaluated monthly from January to December 2024. As shown in Table (4), the results of the current study indicated that the average Biological Oxygen Demand (BOD) values ranged from a maximum of 2.93 ± 0.89 mg·$L^{-1}$ at the first station to a minimum of 2.25 ± 0.76 mg·$L^{-1}$ at the second station. Statistical analysis revealed no significant differences between the stations and no significant differences across the months at a significance level of $P \leq 0.05$.

Active nitrates recorded the highest average value of 16.78 ± 5.10 mg·$L^{-1}$ at the first station and the lowest of 14.12 ± 4.43 µg·$L^{-1}$ at the third station. Again, statistical analysis showed no significant differences between stations or months ($P \leq 0.05$).

The ammonium ion ($NH_4^+$) showed the highest mean and standard deviation of 9.33 ± 3.66 mg·L⁻¹ at the first station and the lowest value of 6.55 ± 2.31 mg·L⁻¹ at the third station. In this case, statistical analysis indicated significant differences between the first and third stations ($P \geq 0.05$), although no significant differences were observed between months.

Meanwhile, the average values of active phosphorus ranged from a maximum of 3.03 ± 1.05 mg·L⁻¹ at the first station to a minimum of 2.46 ± 0.75 mg·L⁻¹ at the second station. Statistical analysis showed no significant differences between stations or months ($P \leq 0.05$).

**Table 4.** Mean, standard deviation, and highest and lowest values for environmental variables

| Environmental factors | Stations | Mean± Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|
| $BOD^5$ Mg. $l^{-1}$ | St.1 | 2.93 ± 0.89 | 1.70 | 4.60 |
| | St.2 | 2.25 ± 0.76 | 1.20 | 3.50 |
| | St.3 | 2.36 ± 0.94 | 0.36 | 3.50 |
| No3 µg. $l^{-1}$ | St.1 | 16.78 ± 5.10 | 8.93 | 25.67 |
| | St.2 | 14.71 ± 4.73 | 9.20 | 25.49 |
| | St.3 | 14.12 ± 4.43 | 8.92 | 24.19 |
| NH4 Mg. $l^{-1}$ | St.1 | 9.33 ± 3.66 | 3.60 | 15.70 |
| | St.2 | 8.04 ± 2.59 | 3.80 | 11.50 |
| | St.3 | 6.55 ± 2.31 | 2.50 | 9.70 |
| Po4 µg. $l^{-1}$ | St.1 | 3.03 ± 1.05 | 1.42 | 5.12 |
| | St.2 | 2.46 ± 0.75 | 0.48 | 3.40 |
| | St.3 | 2.36 ± 0.94 | 0.36 | 3.50 |

The organic pollutants in this study followed a descending pattern, with the first station consistently recording the highest values across all measured environmental variables, followed by the second and third stations. The highest value of Biological Oxygen Demand (BOD) was 4.60 mg·L⁻¹ at the first station, while the lowest was 0.36 mg·L⁻¹. Similarly, the highest active nitrate concentration—25.67 µg·L⁻¹—was observed at the first station, and the lowest—8.92 µg·L⁻¹—at the third station. The ammonium ion showed a maximum value of 15.70 mg·L⁻¹ at the first station and a minimum of 2.50 mg·L⁻¹ at the third. For active phosphorus, the highest concentration was 5.12 µg·L⁻¹ at the first station, and the lowest was 0.36 µg·L⁻¹ at the third.

The elevated concentrations at the first station may be attributed to its proximity to wastewater discharge areas near Hamdan Station, where the water has a high Biological Oxygen Demand due to inputs from sewage and domestic wastewater. These inputs often carry high levels of organic pollutants, particularly phosphates and nitrates **(Listyaningrum, 2022)**.

Alternatively, the increased concentrations of organic matter may result from nitrogen and phosphate compounds originating from fertilizers, pesticides, and industrial chemicals—substances that are resistant to microbial breakdown in aquatic environments **(Setyawan & Hermawan, 2024)**.

The annual average of the Organic Pollution Index (OPI) recorded the highest value of 194.42 at the first station and the lowest value of 151.54 at the third station. Both values fall within the "very poor" category according to the index classification shown in Fig. (2).

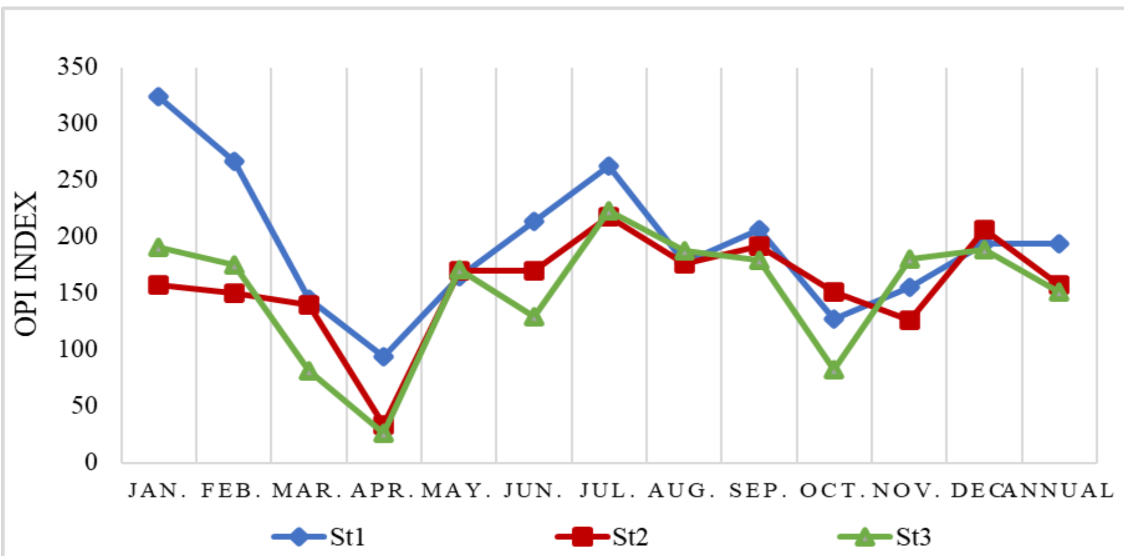


**Fig. 2.** Changes in Organic Pollution Index (OPI) values

The values of the Organic Pollution Index (OPI) showed slight fluctuations, ranging from a maximum of 324.27 at the first station in January—classified as *very poor*—to a minimum of 26.58 at the third station in April, which was classified as *good* according to the index classification (Table 2). The first station consistently recorded the highest values throughout most of the study period.

The results, as illustrated in Fig. (2), demonstrated a clear downward trend in OPI values from the first to the third station. This suggests that pollutant concentrations had the greatest impact at the first station and gradually decreased downstream. This pattern is likely due to the direct discharge of untreated sewage from the Hamdan Wastewater Station into the water, which elevates the levels of Biological Oxygen Demand (BOD), nitrates, ammonium ions, and active phosphates. As water flows toward the second and third stations, a slight dilution of pollutants may occur.

Another contributing factor could be the opening of the Shatt al-Basra Canal regulator, allowing pollutant-laden water from the canal to enter the Khor Al-Zubair waterway. A previous study **(Galo & Resen, 2024)** confirmed increased levels of organic pollutants in the Shatt al-Basra Canal. Additionally, human activity near the first station—particularly the presence of numerous residential units that raise livestock and pets—likely contributes further to organic pollution levels.

An analysis of the principal components in Fig. (3) revealed that the OPI value was significantly correlated with active nitrate concentrations, followed by ammonium ions throughout the study period. While active phosphates and BOD also showed a direct correlation with the OPI, their impact was comparatively less **(Hachi *et al.*, 2022)**.

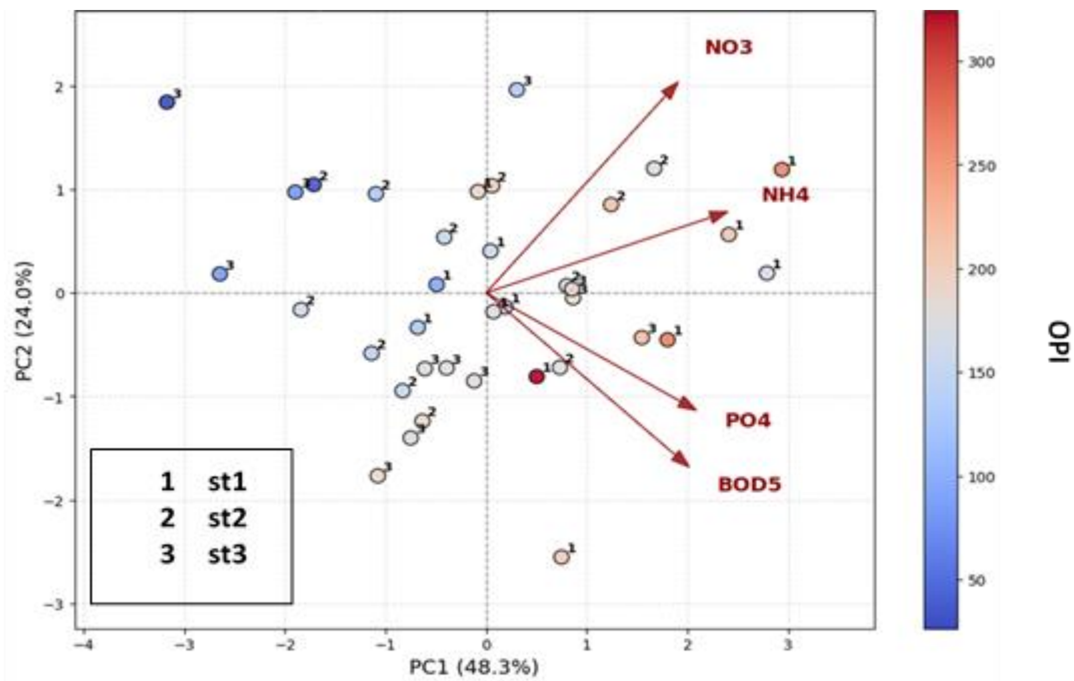


**Fig. 3**. The PCA analysis between OPI and the main factors

The Organic Pollution Index (OPI) recorded higher values during the winter months. This can be attributed to the runoff of organic matter from surrounding lands due to increased rainfall and water flow into the Khor Al-Zubair channel, which leads to greater oxygen consumption and elevated concentrations of nitrogen and phosphorus compounds **(Al-Imarah *et al.*, 2006)**.

Similarly, high OPI values were observed during the summer months, likely due to increased evaporation and lower water levels, which concentrate nitrogen and phosphorus compounds. **Al-Asadi and Al-Hajouji (2019)** noted that the study area experiences extended daylight hours and intense, direct sunlight during summer, promoting evaporation and reducing water depth.

In contrast, surface water flow decreases significantly during summer, further contributing to the concentration of pollutants. The lowest OPI values were recorded during the spring and autumn seasons, possibly due to increased nutrient uptake by plankton, leading to lower concentrations of nitrogen and phosphorus. Another contributing factor may be higher water levels and dilution during tidal inflows, which help flush pollutants and reduce nutrient concentrations **(Ali, 2021)**.

## CONCLUSION

The organic pollution index was used as an effective tool for temporal and spatial assessment of organic pollutants. The results showed that Khor Al-Zubair water was generally organically polluted, particularly in the northern part of the canal, and fell into the very poor category throughout the study period. This was due to the discharge of untreated sewage directly into the canal, as well as the ingress of polluted water from the Shatt Al-Basra Canal.

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