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WATER QUALITY EVALUATION OF DIWANIYAH RIVER USING THE NEMEROW POLLUTION INDEX

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ABSTRACT

Diwaniya is one of the middle Euphrates cities through which the Euphrates River passes through. The Euphrates section that passes through Diwaniya city is called (Shatt al-Diwaniya). This study deals with the river water quality for the period between 2015 and 2023 at that section. The aim of study is to assess the influence of pollution on the sustainability quality of Shatt al-Diwaniyah area using the Nemerow pollution index (NPI) based on artificial neural network (ANN) and regression analysis model (RA). To determine critical water performance parameters for the river section, investigation is required precisely to find out which characteristics and stations contribute to river pollution. Physicochemical water parameters such as Biochemical Oxygen Demand (BOD_5), Total Dissolved Solid (TDS), pH, Dissolved Oxygen (DO), Nitrate (NO_3), and phosphates (PO_4) along the length of the river were measured by fifteen sites from Diwaniya's river during (2015-2023). NPI was calculated for the water samples in each station of examination. The growing NPI value indicated that the river water quality in this section is deteriorating. Where the river's NPI values vary between 2.14 and 3.48, indicating that its water quality is slightly polluted. Mathematical models of artificial neural networks and regression concluded that the most polluted parameter is phosphate PO_4 which is concentrated in station 15 which recapitulates that river water is not suitable for use as a source of drinking water, besides, it can still be consumed to irrigate agricultural property and plants.

KEYWORDS

Artificial Neural Network (ANN), Euphrates River (Diwaniyah River), Models, and Water quality assessment, Nemerow pollution index (NPI).

1. INTRODUCTION

Rivers are one of the most important surface water resources of great ecological and economic importance, so natural (geological) and unnatural (pollution) influences have always affected the hydro-chemical composition and quality of water. Continuous monitoring of a river system is thus essential, particularly in developing nations, to determine the impact of environmental variables on water quality for optimal use and environmental sustainability of the resource (Mohsin et al., 2021; Ren et al., 2021). It has been discovered that impurities in river water reduce the level of absorption of solar energy, causing a decrease in the rate of photosynthesis and a slowdown in the water's natural purification activities, with serious consequences of environmental pollution (Mohammed et al., 2022). If waste is to be considered ecologically acceptable, it must fulfil precise standards outlined in legislation and guidelines, therefore, analysis of the physical, chemical, and microbiological properties of water is crucial to determining water quality for optimal uses such as irrigation, drinking, swimming, fishing, and industrial processing (Khudair, 2013; *Mengyang et al.*, 2023). One of these is Nemerow index who developed the index pollution (NPI) that includes significant benefits for the assessment of the water quality: basic mathematical procedure, simple methodology, satisfying integrated effect, personification of high-concentration pollutant impact as well as an efficient tool to evaluate quality of a freshwater environment. According to these studies, examine and analyze the quality applicability of water measurement methods are required. The typical Nemerow index approach yielded wildly varying findings in every component of water quality measurement (Zhang et al., 2018). To determine how each of those factors affects water quality, regular intake is utilized acting as a foundation of the artificial neural network, it is employed as standardized forecast modeling of input factors for wastewater biochemical treatment plants with changing daily water compositions (Dogan et al., 2008; Hu ZD et al., 2018). Poorly treated effluent discharge in the research region impacts humans, animals, plants, and cities. The main aim of the study is to determine the amounts of different pollutants in the Diwaniyah River (Shatt al-Diwaniyah) area using Nemerow Pollution Index (NPI) based on artificial neural network (ANN) and regression analysis (RA).

2. AREA OF STUDY

The Euphrates River is longest river in the Middle East region, extending from Lake Van in Turkey's eastern highlands to the Black Sea. Approximately 40% of the river flows through Turkey, with the remainder 25% through Syria and 35% through Iraq. It is a significant river in Iraq, having a drainage area and an entry on the country's western border (Khaleefa & Kamel, 2021). AL-Diwaniya River is a section of the Euphrates River that is subsequent to the Al-Hilla River. The river represents a principal source of water supply to AL-Diwaniya. After it flows through the district of Sadeer and Al-Hamzah till it fades in the area of Al Rumaythah/Al-Muthanna Governorate (Mohamed & Al-Jubouri, 2017).

Al-Diwaniyah River runs across central Iraq, inside the Al-Qadisiyah governorate, between 31° 30′-32° 14′ N and 44° 42′ 45° 16′ E. It extends for around one hundred -twenty-one kilometers in Al- Qadisiyah governorate. It flows through Al-Saniyah sub-district, central Al-Qadisiyah governorate, Al-Sadeer sub-district, and Al-Hamza district are the four primary administrative divisions for it. The width of river varies between (45-50) m, however it reaches (70 m) in certain places. The depth of river ranges from 2 m to 4 m. It represents a major supplier of fresh water in Al-Qadisiyah governorate for about 696,701 persons representing 51.24% of total population in the government. Besides, center Al-Diwaniyah receives the most water, and the residents rely on the river for necessities that return for being this river presents the only supply for this area (Al-Sulaiman, 2016). It had employed in agriculture because agriculture lands extends along the river pathway. There are various factories in the study area like textile, dairy, and rubber, in addition to an electric power plant. Domestic, industrial wastes, and agricultural are disposed of straight away towards this river without treatment (Al-Asadi & Al-Kafari, 2022).

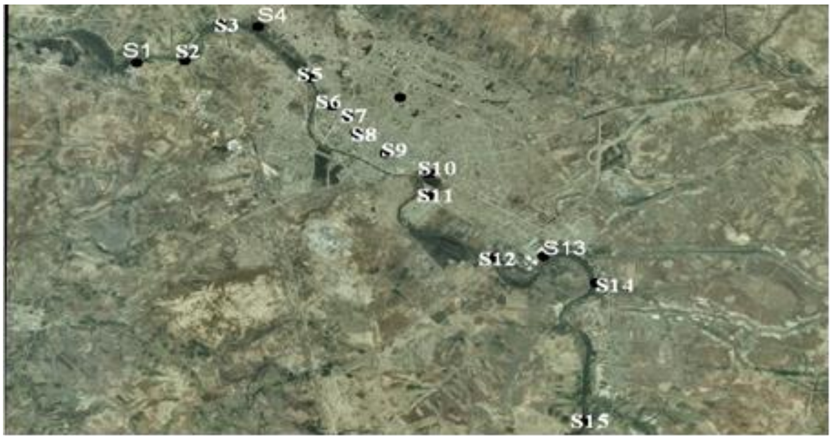

Fig. 1. Map of the Al-Diwaniyah City with the locations of sites along the river (Google earth).

3. STATIONS OF WATER SAMPLING

From 2015 to 2023, river water sampling stations were assembled along the Shatt AL-Diwaniyah River for six parameters; phosphates (PO_4), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD_5), pH, Nitrate (NO_3), and Dissolves Oxygen (DO). Table1 and Fig.1 present data of the locations of sampling stations and the activity near the selected locations.

Table 1 The locations of stations of samples (Scale 20 km)

Symbol sites	Title sites	Location of sites		
		E	N	km
S1	Behind the water supply project	0487434	3541573	1.04
S2	Village included the Fever Hospital	0488467	3541646	1.28
S3	Rail bridge	0489234	3542671	9.39
S4	Branch of sewage after treatment in Um Horse area	0496147	3536319	6.99
S5	Bridge names (Euphrates Bridge)	0491134	3541189	0.92
S6	Bridge names (Corniche Bridge)	0491628	3540408	0.45
S7	Branch of sewage after treatment in Aljazayir area	0491961	3540112	0.46
S8	Bridge names (Almuealaq bridge)	0492126	3539678	0.84
S9	Stream agricultural drainage	0492763	3539124	1.08
S10	The beginning of Imam Sadiq area	0493694	3538584	0.61
S11	The ending of Imam Sadiq area	0493680	3537974	2.22
S12	Residential building group in Diwaniyah	0495104	3536298	8.06
S13	Factory of the textile clothes	0490028	3542562	10.11
S14	Village name (Shaalan Flaih)	0497260	3535599	3.75
S15	Village name (Raji Gulab)	0497054	3531852	3.48

4. METHODOLOGY AND MATHEMATICAL MODEL

4.1. Nemerow Pollution Index

The comprehensive pollution index method is obtained based on the single-factor evaluation method which can qualitatively reflect the degree of comprehensive pollution of water bodies and divide the score according to relevant standards for evaluating the quality of the aquatic environment (Zeng, et al., 2021), therefore, it is defined as a weighted composite calculation of the indicators of each pollution index for the individual pollution index, resulting in a value representing the degree of pollution of the water body, to evaluate the state of water quality pollution (Lu, W & Zhang, 2009). In other words, the pollution index is one of the effective tools for analyzing and communicating data to the public, technicians, managers, and decision-makers (Caeiro et al., 2005). The parameters employed in the computation are BOD_5, TDS, DO, pH, NO_3, and PO_4 to determine the yearly variation of NPI during (2015-2023) based on standards of Iraqi rivers. Nemerow pollution index is applied to assess the pollution-causing parameters, which are the average values for each of the eight years. NPI is calculated for all parameters for each sample examined, allowing the pollution-causing parameters to be identified. The water quality status and suitability for human use, and the impact of river water pollutants were assessed by NPI classification according to the criteria listed in Table 2.

Table 2. Nemerow pollution index and water quality criterion [sited in 10].

Nemerow pollution index	The quality of water
$0 \leq NPI \leq 1$	Meet water quality standards
$1 \leq NPI \leq 5$	Slightly polluted
$5 \leq NPI \leq 10$	Moderately polluted
$NPI \geq 10$	Highly polluted

4.2. Building Artificial Neural Network ANN

To develop an Artificial Neural Network (ANN) for predicting the Nemerow Pollution Index, it needs data collection, data preprocessing, feature selection/engineering, model architecture selection, training the model, hyperparameter tuning, evaluation, model validation, and deployment. It is essential to collaborate with domain experts in environmental science throughout the model development process to ensure the model's accuracy and relevance to real-world pollution prediction tasks (Zuhal & Al-Sulaiman, 2023). For each station of fifteen stations, average of each parameter was calculated during period (2015-2023) and upon previous calculated NPI, the models have been built and that done using artificial neural network. The first model input layers were average parameters of (BOD_5, TDS, DO, pH, NO_3, and PO_4) while the output layer was NPI as shown in Fig. 2.

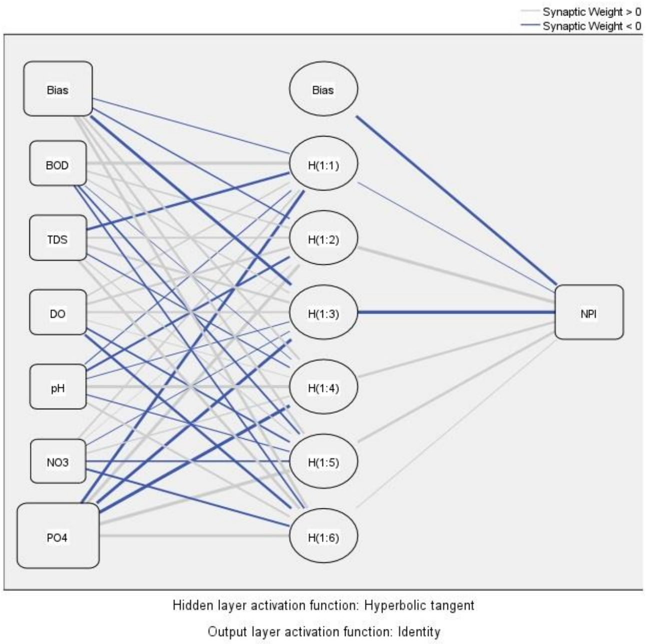

Fig. 2: The layers building of ANN.

The second model was built based on the results obtained from the first model, which is phosphates (PO_4) one of the most important parameters affecting the model, therefore, the new ANN model was built (PO_4) in examination stations as the input layer and NPI as the output layers as shown in Fig. 3.

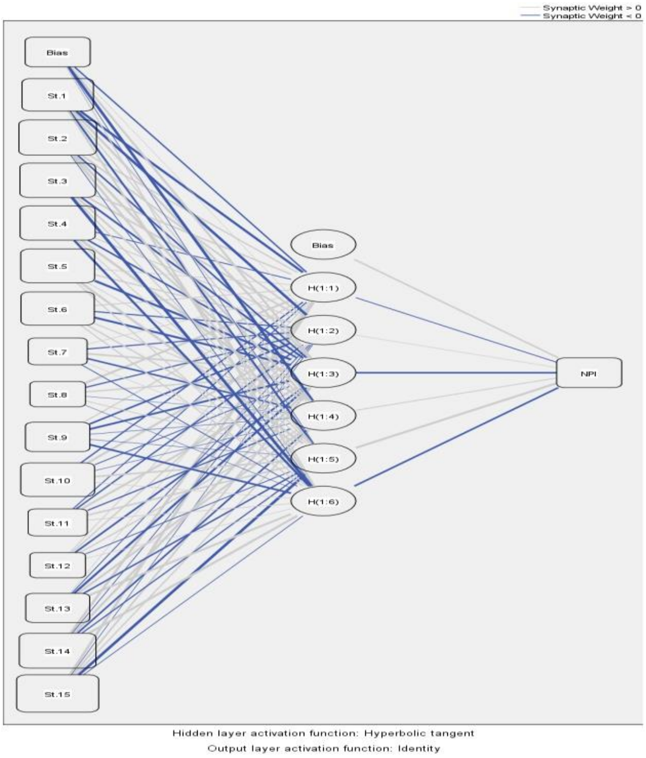

Fig. 3. The layers building of ANN with PO_4 input layer

4.3. Regression analysis

Regression analysis can be used to predict the Nemerow Pollution Index based on various predictor variables such as pollutant concentrations, meteorological data, and geographical factors (Xiaoliang et al., 2016), so, linear regression analysis is performed to determine the relationships among the parameters and Nemerow pollution index, with the pollution index represented as the dependent variable and the parameters acting as independent variables are (BOD_5, TDS, DO, pH, NO_3, and PO_4).

5. RESULTS AND DISCUSSION

5.1. Nemerow Pollution Index

According to the NPI calculations for the stations considered, NPI varied between 2.14 and 3.48 as shown in Figure 4, indicating water quality as slightly polluted as referred to in Table2. The maximum NPI in stations 14 and 15 may due to the accumulation of disposals in the river that come from agricultural sources. Such pollution levels with such sources may seriously endanger human health and public drinking water supplies (Al-Obaidi, 2021; Zhang et al., 2018).

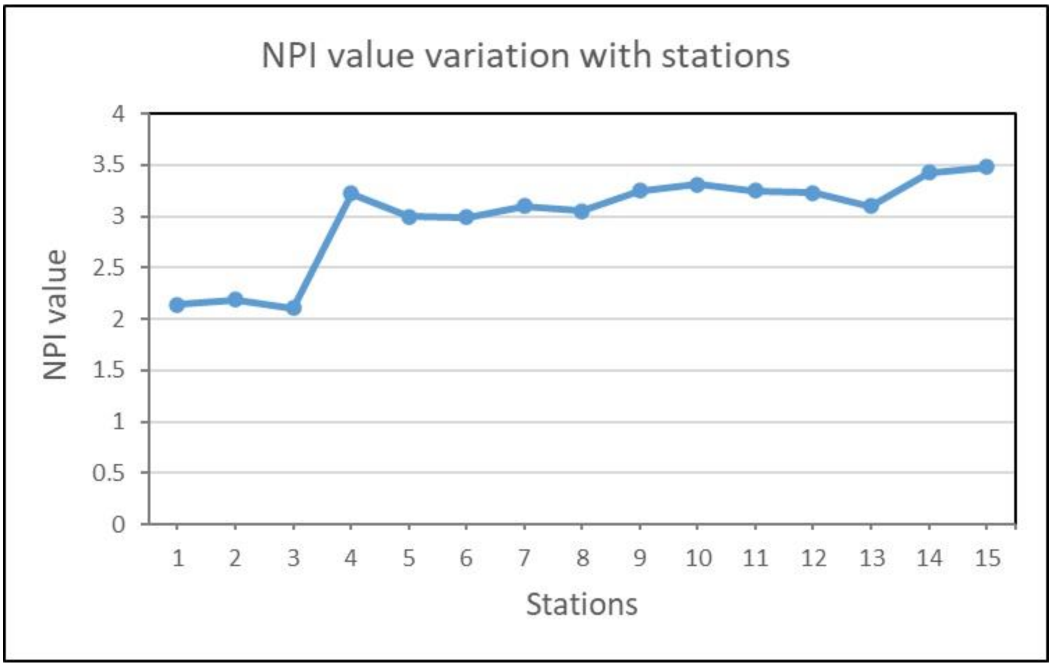

Fig. 4: The variation of NPI in the stations

5.2. Artificial Neural Network ANN

The simulation has been a success with R^2 = 0.9 as shown in Fig. 5 while the method used is normalized to find the effectiveness of the parameters considered. According to the normalization results and the significant results, it was found that phosphate (PO_4) is the most influential factor in the artificial neural network model, and each parameter affects the modeling results in a different percentage, as shown in (Fig. 6 and Table 3).

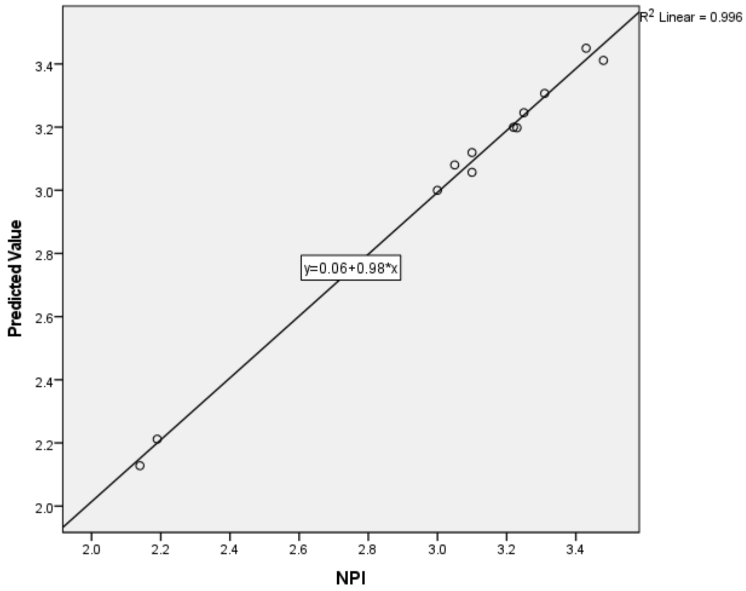

Fig. 5: predicted value of first model.

The second model was also with good conscience having R^2 =0.95 as shown in Fig. 7. The most important parameter was PO_4, especially in station 15 that corresponded with the results of NPI having the maximum value in station 15 (Fig. 8 and Table 4) which may be attributed to complete or partial disposal of wastewater from domestic and industrial treatment plants that causes accumulation and increased phosphate concentrations at sampling sites (Sulthonuddin et al., 2019).

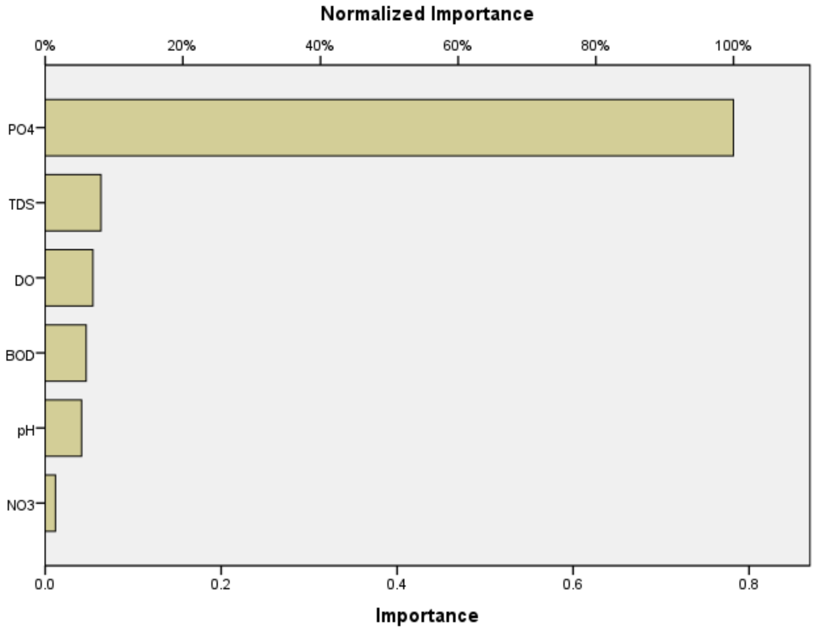

Fig. 6: Normalized importance of parameters.

Table 3. Importance percentage of parameters.

Parameter	Importance	Normalized Importance
BOD	0.047	6%
TDS	0.063	8.1%
DO	0.054	6.9%
pH	0.041	5.3%
NO_3	0.012	1.5%
PO_4	0.782	100%

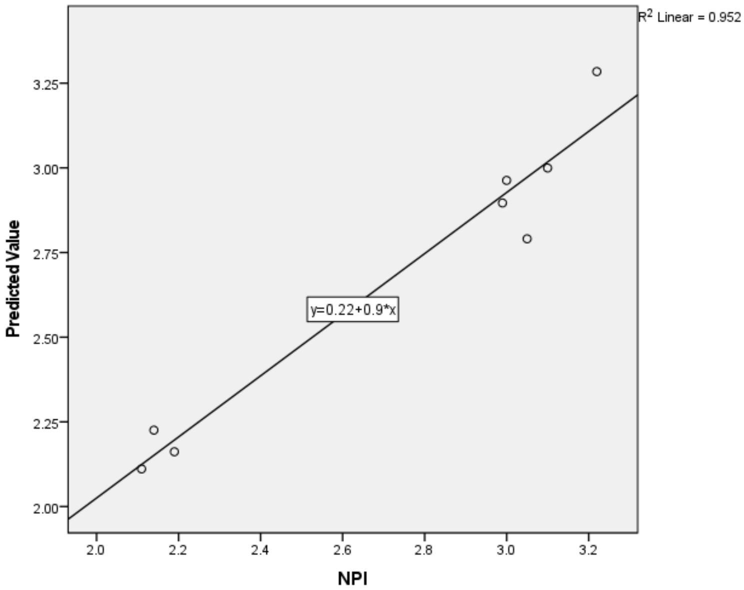

Fig. 7: Predicted value of second model.

Table 4. Importance percentage of parameters.

Parameters	Importance	Normalized Importance
St.1	0.074	68.8%
St.2	0.093	86.8%
St.3	0.087	80.9%
St.4	0.086	80%
St.5	0.082	76.2%
St.6	0.080	74.6%
St.7	0.034	32.2%
St.8	0.024	22.4%
St.9	0.052	48.2%
St.10	0.081	75.9%
St.11	0.036	33.2%
St.12	0.024	22.5%
St.13	0.051	47.2%
St.14	0.091	84.5%
St.15	0.107	100%

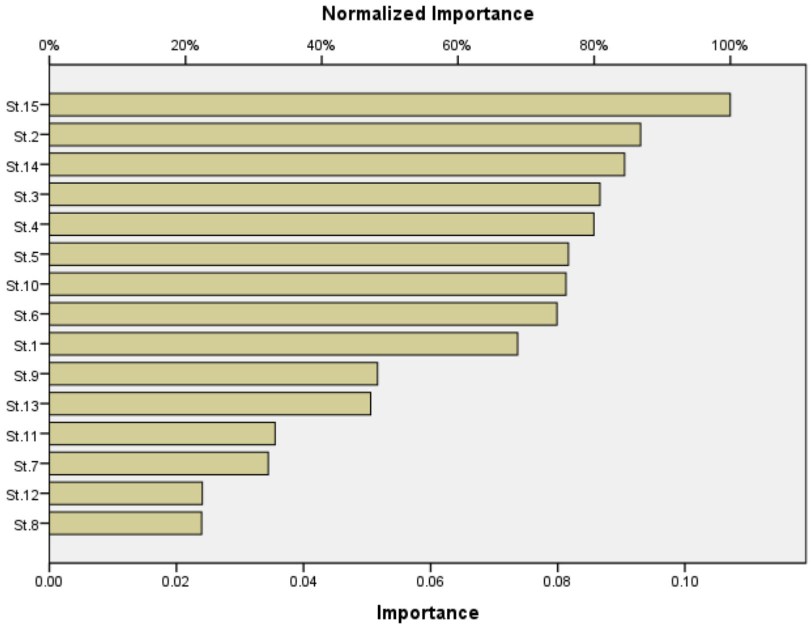

Fig. 8. Normalized importance of parameters

5.2 Regression analysis

The results of partial regression (R^2) showed acceptable relation between dependent variable NPI and the independent variables BOD_5, and pH as 0.583, and 0.646 respectively, whereas relatively weak relation was observed between NPI and NO_3 as 0.094. The R^2 for TDS, DO are 0.67 and 0.769, expressing moderate relation as shown in Fig. 9 and 10. Partial regression of PO_4 indicated that the relationship is good with R^2 1 (Fig. 11) (Alsaqqar et al., 2013).

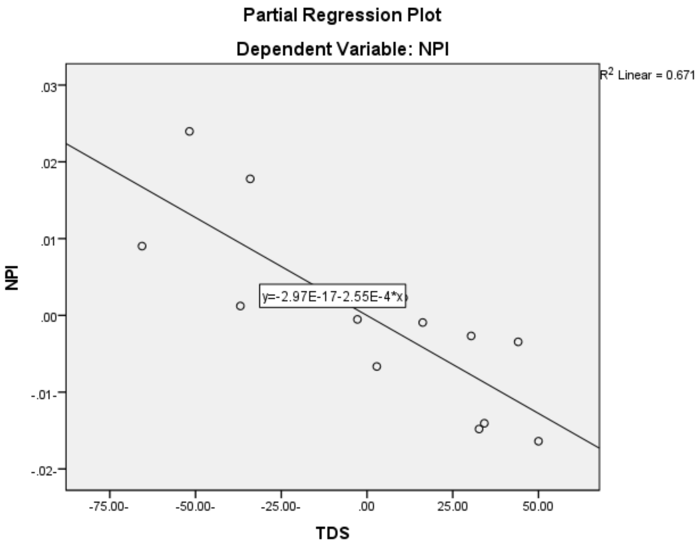

Fig. 9: Partial regression of TDS with NPI

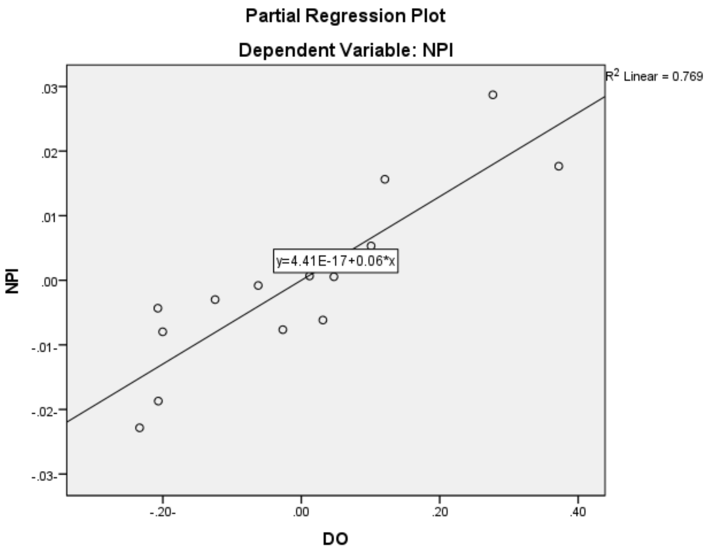

Fig. 10: Partial regression of DO with NPI.

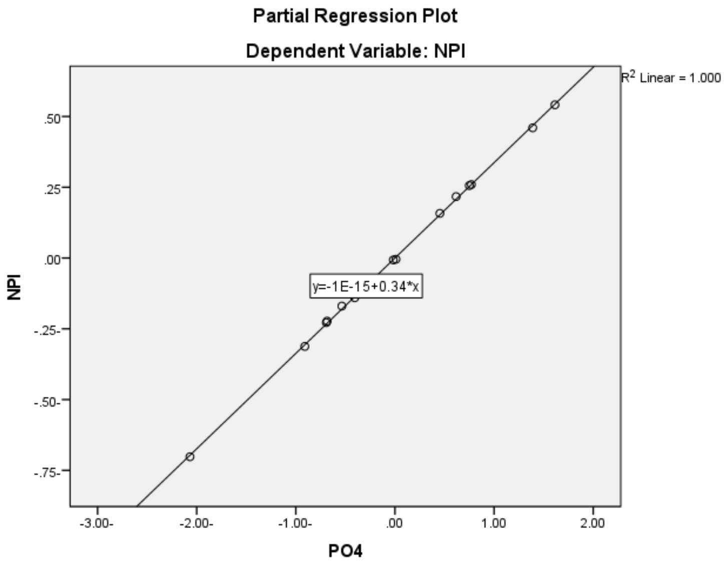

Fig. 11: Partial regression of PO_4 with NPI.

6. CONCLUSIONS

This study concluded that several main conclusions include:

1. the water quality status for the investigated section of Shatt Al-Diwaniya was slightly polluted.
2. the study identified phosphate (PO_4) as the most significant pollutant in the water. This phosphate concentration is particularly high at station 15, primarily due to the accumulation of agricultural waste and the discharge of untreated or partially treated municipal pollutants.
3. the water in this section of the river is deemed unsuitable for use as a source of drinking water due to its pollution levels. Despite not being suitable for drinking, the water can still be used for irrigation purposes. It is noted that it can be used to irrigate agricultural fields and plants.
4. the water quality is slightly polluted and not suitable for drinking, it can still serve a valuable purpose in agriculture by irrigating crops and plants. However, care should be taken to monitor and manage phosphate levels to prevent further pollution and adverse effects on the environment and agricultural productivity.

Recommendations for further research:

Based on the conclusions of the study regarding water quality in Shatt Al-Diwaniya, here are some recommendations for further research based on long-term monitoring, source identification, treatment technologies, impact on ecosystems, and public health risks that can contribute to a more holistic understanding of water quality issues in Shatt Al-Diwaniya and support the development of evidence-based strategies for sustainable water management and environmental protection.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. All authors have contributed to the work reported, have read and approved the final manuscript, and have agreed to be accountable for all aspects of the work.

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