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Water quality of the Shatt Al-Arab River evaluation using the Nemerow pollution index method

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ABSTRACT

Water pollution and dwindling water supplies severely strain the environment. Rapid urbanization, more intensive agricultural practices, and the uncontrolled release of geothermal water all contribute to this problem with water quality. The natural composition of waters is most likely to be altered by human activity. The amount of freshwater in the river has decreased as a result of extensive mining for chlorine in the Shatt Al-Arab River. Determining the surface water quality standards in the river basin was the primary goal of this study, given the rising urban water demand and the associated environmental and health risks linked to pollution. The method of the Nemerow pollution index was used to assess the water quality. The all-encompassing pollution index is used by the Nemerow pollution index method to determine the water quality category, which highlights the most polluting factor while also accounting for the assessment system's other components' contributions. The study's findings show that, over the course of the study, the monitoring indicators of the monitoring stations have attained the "Surface Water Environmental Quality Standard" Category V water quality standard and above. Because the NPI method incorporates the effects of various impacting factors, the water quality was categorized into a grade of more reasonable.

Keywords: Shatt Al-Arab River, water quality, Nemerow pollution index, pollution.

INTRODUCTION

Water covers more than seventy percent of the Earth's surface, making water pollution one of the main environmental issues we are currently dealing with. Because it reduces the quality of the water, water pollution has grown to be a serious global issue that poisons both humans and the environment [1]. The need to comprehend water quality is growing along with awareness of the significance of water, particularly freshwater, for aquatic life and humans. Environmental scientists and ecologists in large numbers are employed to develop management strategies for the world's environmental problems, such as climate change, ecosystem health, and environmental pollution and contamination [2]. There are currently many different approaches that have been developed and employed for evaluating the quality of the water environment [3–9]. Nevertheless, there are no established evaluation standards for either of these approaches to guide the analysis. The most effective method for classifying water quality is to apply pollution index assessment (POIA) techniques [10]. The POIA Method is an evaluation technique that utilizes the index assessment method in conjunction with the physical and chemical characteristics of monitoring data. A scale for evaluating the quality of the water can be created by dividing the monitoring data according to the assessment standards, which produces sub-indices [11]. Depending on how many evaluation projects are chosen based on the monitoring data, the PIA method can be classified as Single factor pollution index (SIFPI) or multi-factor pollution indices (MUFPI) [12]. According to [13], SIFPI analysis can assist us in determining which pollutant is predominant in a given area. The SIFPI approach by itself, however, might not be adequate to handle the combined impact of pollutants on the environment since contaminants have a higher probability of a concurrent effect on the environment [12, 14]. MUFPI are widely used in pollution and contamination studies [15, 16] and can account for the concurrent effects of various pollutants, such as the Nemerow's Pollution Index (NPI) [17]. We know from earlier research that the NPI method and the single factor pollution index method are more developed and have been applied extensively in evaluating the other large and small lakes' water quality and rivers, offering a solid scientific foundation for the preservation of water resources. The NPI is used to analyze the degree of pollution of just one water quality metric in relation to standard values and to evaluate the effects of multiple pollutants on a specific water body. We were able to investigate more in-depth water quality indicators, including demand indicators, eutrophication indicators, and indicators of industrial wastewater discharge, thanks to the WQI assessment [18]. The primary goal of this study was to ascertain the surface water quality standards in the Shatt Al-Arab River Basin (SHAAR) based on the results of a water quality monitoring program and the application of the NPI method. The river basin's polluted zones will be identified using the identified indicators to determine which water quality management actions should be prioritized.

MATERIALS AND METHODS

Area of study

SHAAR is one of the main rivers in Basrah city, Iraq, located between latitudes 30°59'00" N and longitudes 47°26'00" E (Fig. 1). The SHAAR is a river about 200 kilometers in length that is created at the meeting point of the Tigris and Euphrates rivers in the southern Iraqi Basra Governorate town of al-Qurna. The river's southernmost point, which empties into the Arabian Gulf, forms the border between Iran and Iraq. The SHAAR varies in width from about 232 meters at Basra to 800 meters at its mouth. Geologically speaking, the waterway is thought to have formed relatively recently. Originally, the Tigris and Euphrates empties into the Arabian Gulf through a channel that is located farther west. This river has been serving as a first-rate source of drinking water protection zone with the amount of water available. The SHAAR River's hydrological system has changed over the past 40 years, which has resulted in notable changes to the quantity and quality characteristics of the river water [19, 20]. The SHAAR freshwater and saltwater mixing process exhibits both temporal and spatial variations, according to this river's study. As a result, the dynamics of the hydrochemical system are frequently varied and complex along the river, making it difficult to precisely measure the net water discharge [21]. Figure 2 shows the stations take the samples from it.

Sampling and analytical process for water quality

Between January and October of 2022, water samples were taken from each of the four stations (Figure 2). The samples were gathered into 0.5-liter plastic bottles, which were filled after being repeatedly rinsed with the sample. Three samples were obtained for each sampling point. The State Environmental Protection Administration

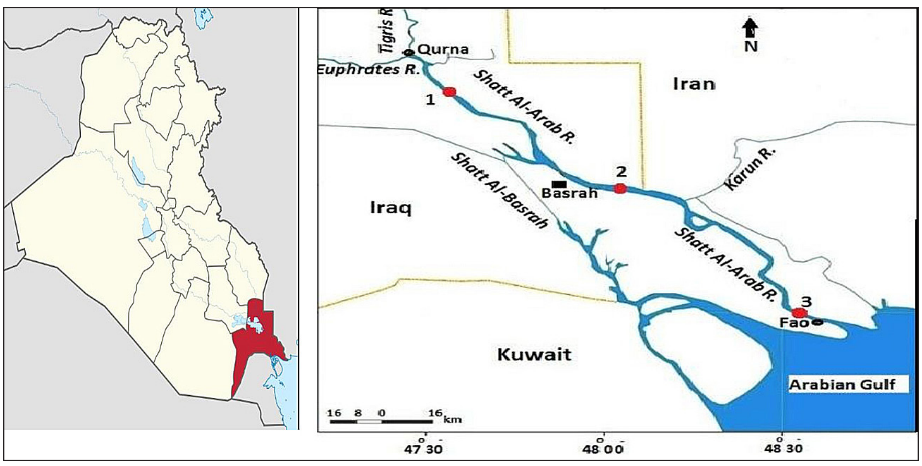

Figure 1. Location map of monitoring SHAAR

Figure 2. The station in the SHAAR

[22] specified the procedures for the preservation, transportation, and analysis of water samples in order to examine the following parameters: pH, total dissolved solids (TDS), chloride (Cl^-), magnesium (Mg^{2+}), potassium (K^+), nitrate (NO_3), sulfate (SO_4^{2-}), calcium (Ca^{2+}), total hardness (TH), and Alkanity (Alk).

Method for assessing pollution index

Single-factor pollution index: The single-factor pollution index (SIFPI) method involves all aspects of the comprehensive assessment of water quality indicators. It does this by utilizing the single indicator with the lowest water quality within the category to determine the overall category of water quality [23]. The pollution index is then calculated to identify the primary pollutants in the water body and the extent of their harm. The formula for the single factor pollution index method is as follows [23, 24]:

$$P = (P_i)_{max} \tag{1}$$

where: P_i is the classification of parameter i, $(P_i)_{max}$ is the maximum classification for all the parameters (the most polluted parameter), and P is the surface water body classification (at the location of the water station used in this study) in accordance with [22].

Nemerow pollution index

Nemerow (1971) made the proposal for NPI for the US Environmental Protection Agency (EPA). The NPI method, which highlights the most polluting factors while also considering the role that other elements play in the evaluation system, is a more thorough methodology for evaluating water quality than the single factor index method. Water quality assessments worldwide widely use NPI, which takes into account the impact of the SIFPI index [23, 25]. and computes an all-encompassing pollution index and a multi-factor, weighted environmental quality index that highlights the maximum values or accounts for the extreme values, in order to assess the quality of the water category. The following is the form of the NPI mathematical formula [26]:

$$NPI = \sqrt{\frac{(\frac{1}{n}\sum_{i=1}^{n} P_i)^2 + [(P_i)_{max}]^2}{2}} \tag{2}$$

where: n is the entire number of parameters related to water quality, Pi is parameter i's relative pollution index, and Pi_{max} is the classification that is maximum for all the parameters. NPI stands for Nemerow Pollution Index.

$$P_i = \frac{C_i}{C_o} \tag{3}$$

where: P_i is the proportion of pollution that the water quality parameter i contributes, C_i is the parameter i's measured value, and C_o is the maximum amount of i that is allowed at the site of water use.

When a contaminant, like pH, has a permissible level that falls between C_0 min and C_0 max,

$$P_{PH} = [C_i - \frac{[\frac{(C_0)_{min} - (C_0)_{max}}{2}]}{(C_0)_{max}}] \quad (4)$$

Evaluation standards

In this study, the environmental quality standards (Table 1) are used as the evaluation criteria.

RESULTS AND DISCUSSIONS

The average value of the studied parameters for surface water from four stations is listed in Table 2. The values of pH, total dissolved solids (TDS), chloride (Cl^-), magnesium (Mg^{2+}), potassium (K^+), nitrate (NO_3), sulfate (SO_4^{2-}), calcium (Ca^{2+}), total hardness (TH), Alkanity (Alk), and the standard values of Iraq (IRQS) are presented in Table 2.

Water quality assessment using SFPI method

By evaluating the overall water quality of a set of indicators, the SFPI method is applied, and the category with the lowest overall water quality indicator is identified by taking a single indicator. Equation 3 is used to calculate the SFPI method. The result of the SFPI is: The results of ten experimentally determined parameters (pH, TDS, Cl, Mg, K, NO_3, SO_4, Ca, TH, and ALK) were contrasted with surface water quality standards in IRQS [27] in order to determine the classification of water quality for every parameter. We used the station average concentration value to evaluate the quality of the water. According to the guidelines [27], the worst individual pollutant is evaluated to determine the station's water quality grade. The data for the four station indicators in Figure 2 are computed using Equation 3, and the SIFPI value for each station indicator is displayed in Table 3 below.

According to the [27] and the monitoring results (Table 3), If the water parameter Pi value is greater than one, It shows whether there is an excess or concentration of it, and the specific parameter may cause pollution to the water bodies studied. For the Qurna, Karmat Ali, and Ashar stations, the highest index values contributed parameters caused to pollution were by TDS, Cl, Ca, and TH. But at the Sehan station, the highest index values contributed parameters caused to pollution were by TDS, Cl, Mg, K, SO_4, Ca, and TH.

Numerous findings of the pollution index

The NPI was used to analyze the level of pollution of a single water quality parameter in relation to standard values and to evaluate the effects of multiple pollutants on a specific water body. Each station index therefore reflects both the highest relative evaluated value and the average of all relative values. The NPI method compromised between the worst evaluated pollutants and the

Table 1. Classification standards for surface water quality

Grade of water quality	Clean	Slightly polluted	Moderately polluted	Heavy polluted	Seriously polluted	References
Class	I	II	III	IV	V	
NPI	<0.7	0.7≤ NPI <1.0	1.0≤NPI<2	2.0≤NPI<3.0	>3	[24]

Table 2. Averaged measured and standard values of Iraq of the studied parameters

Parameter	Unit	Value				IRQS [27]
		Qurna	Karmat Ali	Ashar	Sehan	
PH	----	8.4	7.8	7.8	7.86	8.5
TDS	mg/l	1610	2404	2481	8638	1500
Cl	mg/l	495	739	768	4052	250
Mg	mg/l	69	100	105	336	150
K	mg/l	6	10	11	54	20
NO_3	mg/l	1.77	1.72	1.5	2.75	45
SO_4	mg/l	321	357	386	486	400
Ca	mg/l	118	145	151	277	75
TH	mg/l	587	786	821	2111	500
Alk	mg/l	165	174	162	162	200

Table 3. SIFPI classification result

Stations	pH	TDS	Cl	Mg	K	NO_3	SO_4	Ca	TH	ALK
Qurna	0.988	1.07	1.98	0.46	0.3	0.039	0.803	1.57	1.174	0.825
Karmat Ali	0.918	1.603	2.956	0.67	0.5	0.038	0.893	1.93	1.572	0.87
Ashar	0.918	1.654	3.072	0.7	0.55	0.033	0.965	2.01	1.64	0.81
Sehan	0.925	5.79	16.208	2.24	2.7	0.061	1.215	3.69	4.222	0.81

Table 4. Outcome of the Nemerow pollution index classification

Sta.	pH	TDS	Cl	Mg	K	NO_3	SO_4	Ca	TH	Alk	NPI
Qurna	0.988	1.073	1.6	0.46	0.3	0.0393	0.803	1.57	1.174	0.825	1.29
Karmat Ali	0.917	1.603	2.956	0.667	0.5	0.0382	0.8925	1.933	1.572	0.87	2.285
Ashar	0.917	1.654	8.228	0.7	0.55	0.0333	0.965	2.013	1.642	0.81	5.95
Sehan	0.925	5.759	16.208	2.24	2.7	0.061	1.215	3.69	4.222	0.825	11.78

average evaluated pollutants in a weighted environmental quality index [17]. The river water is typically Class V and Class VI (heavy and severely polluted), according to the NPI results (Table 4).

Chloride was the most degraded pollutant that affected the water quality grade. The NPI approach was determined to be appropriate for accurately representing the overall state of the water

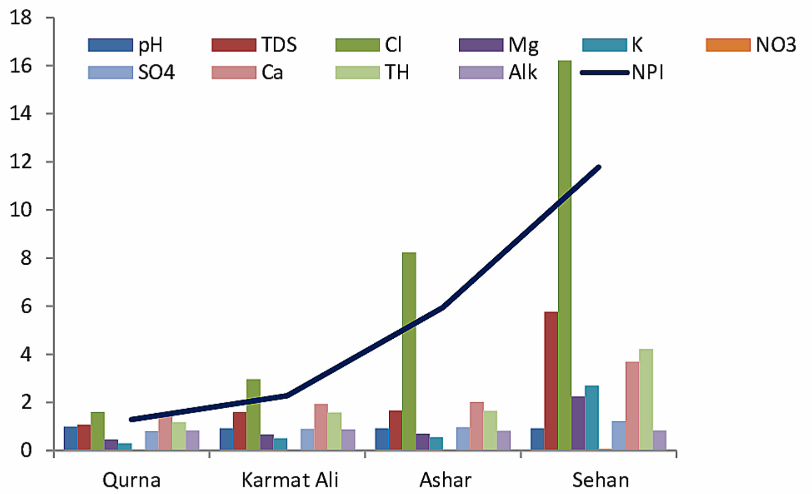

Figure 3. Water quality spatial trend in the stations Rivers Basin and NPL

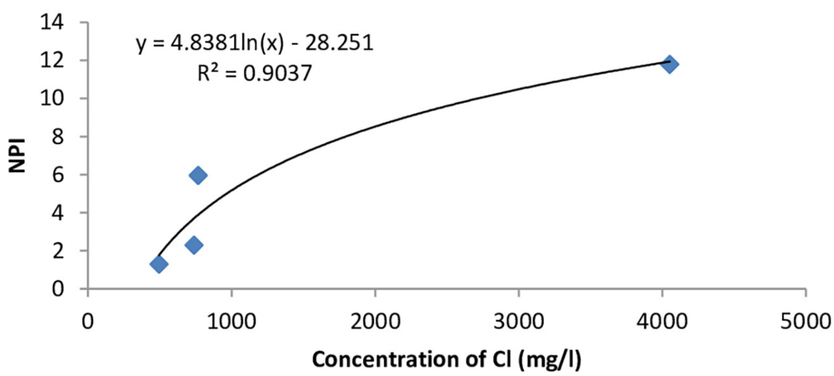

Figure 4. Spatial variation of the Nemrov pollution index (NPI) and total chlorine (Cl) at the four stations in the river

quality. (Fig. 3) analyzes the spatial trend of the water quality in the four stations. As per the findings, there is a downward trend in the water quality status at these stations, which is in line with the declining trend of chlorine (Cl) in the river water (Fig. 3). The NPI method takes into account the average of the single factor indices, which accurately represents the degree of water pollution, and the more polluting indicators, making it more thorough when evaluating water quality than the single factor index method when compared to the evaluation results of the SIFPI method [28]. Figure 4 shows the relation between NPI and the concentration of Cl. A logarithmic regression equation between the NPI and Cl concentration at the stations (Equation 5) revealed that there is a strong linear correlation ($R^2 = 0.9037$) between the NPI and Cl of stations.

$$NPI = 4.8381 \times \ln(Cl) - 28.251 \tag{5}$$

CONCLUSIONS

Because of the growing population and increased demand for water resources, the research area is continuously under threat. There is currently little understanding of the pollution index assessment (POIA) method for classifying the water quality of a river heavily influenced by human systems. Human activity is most likely to change the organic makeup of the liquid. The NPI method has been used in this study. Shatt Al-Arab River in Basrah was impacted for surface water quality classification. It was discovered that the single-factor pollution index method, or holistic approach, could differentiate between different pollutant characteristics and be used to categorize the river system's water quality. Analysis of the various outcomes revealed that the worst-evaluated index has a significant influence on the SIFPI classification, which is more conservative. However, because the NPI method integrates the combined effects of multiple indices, it grades the water quality into more reasonable categories.

When the POIA results were applied to the river's water quality management, it was discovered that there was a direct cause-and-effect connection between the water's concentration of chlorine (Cl) and its quality; high NPI values, which indicate poor water quality monitoring, were associated with high Cl concentration. Thus, in order to prioritize water quality management measures in the SHAAR, polluted zones can be characterized using Cl concentration and the NPI method.

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