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APPLICATION OF POLLUTION INDEX (PI) TO ASSESS THE WATER QUALITY BASED ON PHYSICOCHEMICAL PARAMETERS OF QILIASAN AND KANI-BAN STREAMS IN SULAIMANI CITY

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Abstract

This investigation focused on two streams, named Major stream Qiliasan and Minor stream Kani-Ban, which converge to form the Tanjero River. The assessment of water quality in both Qiliasan and Kani-Ban streams was conducted at five unlike locations during two seasons (winter and summer) in the year 2023. In this study, the Comprehensive Pollution Index was utilized to evaluate the water quality status of Qiliasan and Kani Ban streams, and to determine the physiochemical parameters responsible for water pollution. These parameters include: water temperature, pH, electrical conductivity, turbidity, total dissolved solids, color, calcium, magnesium, chloride, and sulfate. The Comprehensive Pollution Index was found to be higher during the summer than in the winter, making it a more clear indicator of pollution in the summer. The results based on the calculation of the Comprehensive Pollution Index indicated that all stations were found to have moderately to severely polluted water in the summer season, with Comprehensive Pollution Index values ranging from 1.18 to 2.57. However, during the winter season, the water quality showed slightly to moderately contamination, with Comprehensive Pollution Index values ranging from 0.86 to 1.53.

Keywords: Comprehensive Pollution Index, Water Pollution, Wastewater, Sewage effluent.

تطبيق مؤشر التلوث (PI) لتقييم جودة المياه اعتمادا على المعايير الفيزوكيميائية لمجريي قلياسان وكاني بان في مدينة السليمانية

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الخلاصة

تم التركيز في هذا البحث على مجريين للمياه وهما مجرى رئيسي قلياسان ومجرى ثانوي كاني بان واللذان يلتقيان لتكوين نهر تانجرو. تم تقييم جودة المياه في خمس مواقع مختلفة على طول المجريين ولفصلين مختلفين (الصيف والشتاء) للعام 2023. في هذه الدراسة، تم استخدام مؤشر التلوث الشامل لتقييم حالة جودة المياه في مجاري قلياسان وكاني بان، ولتحديد معايير فيزوكيميائية المسؤولة عن تلوث المياه. وتشمل هذه معايير: درجة حرارة الماء، ودرجة الحموضة، والتوصيل الكهربائي، والعكارة، والمواد الصلبة الذائبة الكلية، واللون، والكالسيوم، والمغنيسيوم، والكلوريد، والكبريتات. وتبين أن مؤشر التلوث الشامل يكون أعلى خلال موسم الجفاف منه في موسم الأمطار، مما يجعله مؤشرا أكثر وضوحا للتلوث في موسم الجفاف. اشارت النتائج المستحصلة بالاعتماد على استخدام مؤشر التلوث الشامل بان المياه ملوثة بدرجة متوسطة الى شديدة في فصل الصيف حيث تراوحت قيم مؤشر التلوث الشامل من 1.18 الى2.57 بينما في فصل الشتاء اظهرت النتائج بان المياه ملوثة بدرجة ضئيلة الى متوسطة حيث تراوحت قيم مؤشر التلوث الشامل من 0.86 الى 1.53.

كلمات مفتاحية: مؤشر التلوث الشامل، تلوث المياه، مياه الصرف، مياه الصرف الصحي السائلة.

Introduction

In the first quarter of the 21th century, a group of scientists, including (1, 4, 9, 10, 26 and 27) has collaboratively recognized climate change, species extinction, air and water pollution, water crisis, natural resources consumption, deforestation, and soil degradation as the primary environmental challenges. Water is an essential natural resource crucial for the survival of all living beings on Earth. It serves vital functions in a range of activities, including drinking, domestic use, recreation, irrigation, fishery, and the nurturing of aquatic life (20). Over the past decades, the quality of global water has rapidly deteriorated due to the rapid growth of the population, urbanization, technological advancements, and accelerated industrialization. Water pollution has become a significant problem caused by human activities, disrupting ecosystems and posing risks to public health (22 and 25). With the rapid development of the economy, water pollution has increasingly become a more pressing issue, posing a substantial threat to water resources (2 and 21). According to (16), the water pollution index provides a combined assessment score for environmental parameters, allowing the interpretation of water quality. The Comprehensive Pollution Index (CPI) is a measure utilized to appraise and quantify the overall pollution level in a particular area or environment. It is a comprehensive index that takes into account multiple pollution indicators and parameters to provide a holistic evaluation of environmental pollution. To assess water quality, numerous indexes have been developed. In this study, the Comprehensive Pollution Index (CPI) was utilized to evaluate the water quality status of Qiliasan and Kani Ban streams, and to determine the physiochemical parameters responsible for water pollution. The main objective of this research is to evaluate and classify the water pollution in the Qiliasan and Kani Ban streams using the Comprehensive Pollution Index (CPI).

Materials and Methods

Study area description: In this study, two streams, specifically the major stream Qiliasan and the minor stream Kani-Ban, were selected. These streams converge to create the Tanjero River. Additionally, the Tanjero River receives sewage effluent from various sources. One of the main tributaries contributing to the Tanjero River is the Kani-Ban stream, located south of Bakrajo at a distance of approximately 3 km. The water depth of this stream varies from 0.3 m to 1 m, while its width ranges between 3 m and 5 m (5). Another tributary contributing to the Tanjero River is the Qiliasan stream, originating from the abundant outflow of Sarchinar springs. It connects with the Chaq-Chaq stream near Qiliasan village, eventually forming the Qiliasan stream. The Qiliasan stream is subject to various sources of pollution along its course. The Sarchinar sewage outlet box and several small sewer pipelines contribute to this contamination. The stream's depth varies from 0.5 to 1.5 meters, and its width fluctuates between 5 to 10 meters. The flow rates of the stream display notable variations, ranging from 201,372 to 2,617 cubic meters per day between wet and dry seasons (6).

Collection and Analysis of Samples: For the current research, surface water samples were collected in clean one-liter polyethylene bottles (plastic containers) during two seasons (summer and winter) in the year 2023. The sampling locations were divided into two streams, Qiliasan and Kani-Ban. Along the Qiliasan Stream, three sites (S1, S2, and S3) were selected, while sample sites (S4 and S5) were chosen along the Kani-Ban stream (Figure 1 and Table 1). Prior to collecting the samples, the containers were thoroughly rinsed with water, repeating the rinsing process 2 to 3 times. After collection, the water samples were promptly transported to the Soil Chemistry laboratory of the College of Agricultural Engineering Sciences at the Department of Natural Resources. They were then refrigerated at 4°C to preserve the samples until the analysis could be conducted. During the water sample collection, several parameters were measured using specific instruments. A portable pH meter (Multi 340i/SET multi-parameter instrument WTW Company-Germany) was used to measure the pH and temperature (T ◦C) of the water sample. Additionally, the total dissolved solids (TDS) and electrical conductivity (EC) were analyzed with a portable EC-meter, model LF318. Moreover, the turbidity of the water samples was determined in the laboratory on the day of collection using the

Photo Flex Turb. turbidity meter from WTW Company in Germany. As for the remaining water quality parameters such as Color, Calcium, Magnesium, Chloride, and Sulphate, their analysis was carried out in the laboratory using the Photo Lab spektral model (82362 Weilheim) from WTW Company in Germany (17).

Table 1: Geographic coordinates of the collected water samples.

Sampling site codes	Location name	Longitude	Latitude	Description
S1	Qiliasan Stream	45° 22' 29"E	35° 33' 60"N	Below Qiliasan Bridge
S2	Qiliasan Stream	45° 22' 19"E	35° 33' 12"N	Near to Awabara bridge
S3	Qiliasan Stream	45° 22' 24"E	35° 31' 34"N	Near to KaniGoma bridge
S4	Kani-Ban Stream	45° 21' 33"E	35° 31' 44"N	Near to Bngrd Village
S5	Kani-Ban Stream	45° 21' 39"E	35° 31' 15"N	Below Baba-Ali Bridge

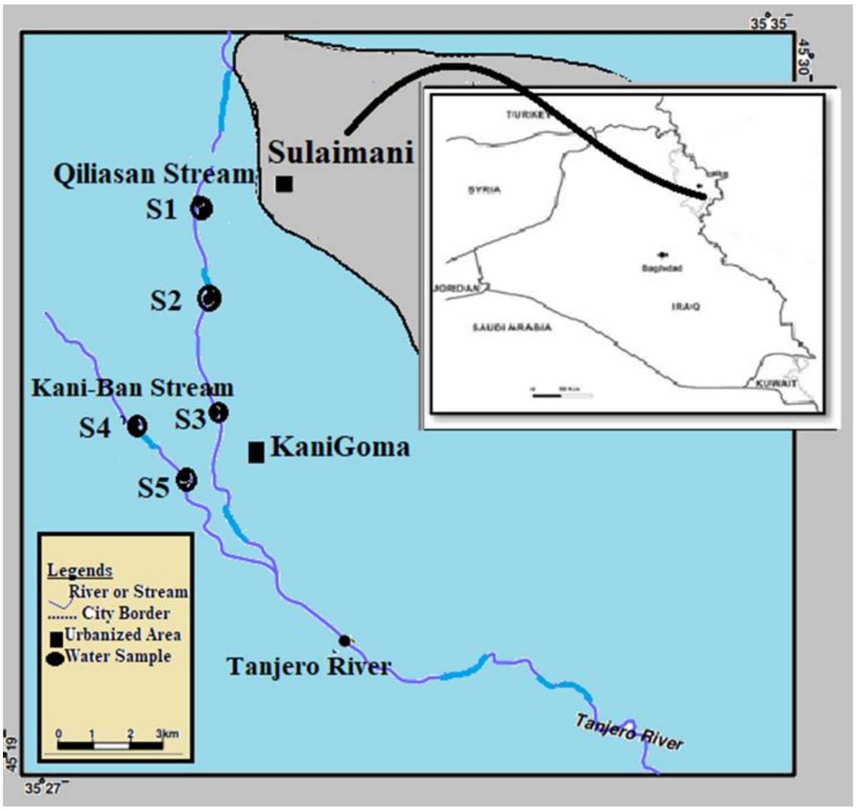

Figure 1: The study area and the locations of the sampling stations.

Comprehensive Pollution Index (CPI): The Comprehensive Pollution Index (CPI) is utilized to assess the pollution level of water sources by analyzing various physicochemical parameters (23). In this research, we employed ten water quality parameters to compute the Comprehensive Pollution Index (CPI), which is mathematically expressed as follows:

$$CPI = \frac{1}{n} \sum_{i=1}^{n} PI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:

CPI = Comprehensive polluted index

n = parameters number

PI = pollution index number i .

PI should be computed from the equation below:

$$PI= \frac{Ci}{Si} \text{ ……………..…... } 2$$

Where:

Ci = Concentration of parameter in water

Si = Standard permissible concentration

Table 2: Classification of CPI (13).

CPI	Class
0 – 0.2	Clean
0.21 – 0.40	Sub-clean
0.41 – 1	Slightly polluted
1.01 – 2.00	Moderately polluted
≥2.01	Severely polluted

Results and Discussion

Analysis of physicochemical properties: Table 3 displays the results relating to the physicochemical parameters of the water samples obtained from the five chosen stations.

Table 3: Results of the physicochemical parameters of the study area.

Parameters	Units	Season	Qilisan Stream			Kani-Ban Stream	
			S1	S2	S3	S4	S5
pH	-	Winter	7.39	7.52	7.49	7.42	7.37
		Summer	7.75	7.89	8.10	7.78	7.95
Temperature	ºC	Winter	11.1	11	11.2	10.4	9.9
		Summer	19.3	20.1	21.5	19.1	20.5
EC at (25)	µs/cm	Winter	441.73	437.73	571.74	666.72	710.71
		Summer	660.54	685.62	1120.10	976.33	1025.41
TDS	mg/L	Winter	440	439	569	666	727
		Summer	530	522	993	874	967
Turbidity	NTU	Winter	10.7	11.3	21.8	11	23.3
		Summer	15.6	17.3	55.4	36.2	54.7
Color	Hazen unit	Winter	10.9	11.6	36.3	35.9	55.6
		Summer	12	11.8	50.2	40.6	56.4
Calcium	mg/L	Winter	65	72	84	51	90
		Summer	120	135	147	151	173
Magnesium	mg/L	Winter	39.2	42.7	42	43.3	42
		Summer	46	52.2	59.3	64	62
Chloride	mg/L	Winter	56	64	73	67	84
		Summer	60	76	110	70	82
Sulfate	mg/L	Winter	91	93	138	87	155
		Summer	128	166	287	106	210

In the chemistry of water, pH is considered one of the most significant and frequently utilized tests. The pH value in water is subject to the influence of both organic and inorganic compounds. Throughout this investigation, the pH values of the water samples ranged from 7.37 to 8.10. The lowest pH reading of 7.37 was documented at site S5 during the winter season, whereas the highest pH reading of 8.10 was recorded at site S3 during the summer season. At all the studied stations, the pH levels were found to be on the alkaline side.

Temperature emerges as a crucial factor affecting the majority of physical, chemical, and biological properties of water, thereby influencing water chemistry. In rivers, it experiences continuous variations due to the dynamic nature of environmental conditions (8).

In the present study, the water temperature at the five study sites fell within the range of 9.9°C to 21.5°C. The highest recorded temperature 21.5°C was observed at site (S3) during the summer season, while the lowest temperature 9.9°C was recorded at site (S5) during the winter season. These fluctuations in temperature could be attributed to factors such as increasing pollution rates, low water levels, high air temperatures, and the discharge of wastewater at site (S3).

Conductivity is a rapid method of assessing the presence of dissolved solids in water. It quantifies the water's ability to conduct electricity, a property dependent on the temperature and concentration of dissolved substances (18 and 24). The conductivity of water exhibited varying absolute values, ranging from 441.73 μS/cm at site (S1) during the winter season to 1120.10 μS/cm at site (S3) during the summer season. These elevated conductivity levels could be attributed to the direct discharge of sewage wastewater into the stream through specific discharge points or the introduction of pollutants through human activities.

Total dissolved solids (TDS) in water refer to the amount of dissolved matter present. The TDS levels ranged from 439 to 993 mg/L, with the lowest value recorded at site (S2) during the winter season. On the other hand, the highest value was observed at site (S3) during the summer season. The higher TDS concentrations observed in this study are likely a result of sewage effluents directly flowing into the stream through pipes, canals, and open drains, leading to water pollution. Consequently, the presence of various minerals and dissolved solids in higher concentrations may decrease the water's palatability.

The values of turbidity ranged from 10.7 to 55.4 NTU, with the highest turbidity value observed at Qilisan Stream (S3) during the summer season, and the lowest value at the same Stream (S1) during the winter season. The highest value of turbidity in this work may be attributed to increasing quantity of waste discharge, domestic activities, and algal growth (20).

The presence of color in water is easily noticeable and can significantly impact its aesthetic value, even in small quantities (7). Based on the data presented in (Table 3), the Color values in the studied water sample ranged from 10.9 to 56.4 Hazen units. The highest Color value of 56.4 was recorded at site (S5) during the summer season, while the lowest value of 10.9 was observed at site (S1) during the winter season. Elevated color levels in water samples could be attributed to pollution from domestic and industrial effluents contaminating the water source.

During most of the investigation period and at all stations, the concentration of calcium in water consistently remains higher than that of magnesium. This phenomenon could be attributed to the calcium ion's greater tendency to react with carbon dioxide compared to magnesium, as noted by (14 and 19). The Calcium contents of the water samples displayed variations within the range of 51 to 173 mg/L. The highest value was recorded at site (S5) during the summer season, whereas the lowest value was observed at site (S4) during the winter season.

Particularly, both these values were recorded in Kani-Ban stream. The increase in Calcium concentration at site (S5) probably due to the quantities of sewage effluents discharged to the Kani-Ban stream from Bakrajo boxes. According to the present study, the water samples revealed a concentration of Magnesium ions ranging from a minimum value of 39.2 mg/L, measured at site (S1) during winter, to a maximum value of 64 mg/L, measured at site (S4) during summer. The presence of Magnesium in the water is possibly attributed to the recharging district, where water interacts with dolomite and dolomitic limestone from the Qamchuqa Formation (15). However, it's important to note that higher concentrations of magnesium can represent water unpalatable and increase its hardness (3).

The presence of chloride in freshwater has consequences for plants and organisms, affecting their reproductive rates, increasing species mortality, and modifying the overall characteristics of the nearby ecosystem. Similarly, sulfate can be more problematic as it is often found in higher concentrations. In relatively small to moderate quantities, chloride and sulfate ions can improve the taste of water, as noted by (13). Throughout the study period, the concentrations of chloride and sulfate in water samples varied between 56 to 110 mg/L and 128 to 287 mg/L, respectively. The lowest values for both chloride and sulfate were observed at site (S1) during winter, while the highest values were recorded at site (S3) during summer, as indicated in (Table 3). These elevated chloride and sulfate levels could be attributed to increased anthropogenic, animal, agricultural, and industrial activities, resulting in a significant discharge of sewage wastewater, which serves as a major source of pollution.

Water Pollution Index: The Comprehensive Pollution Index (CPI) method is utilized as a singular assessment approach, employing a specialized mathematical model to compute the index and assess the degree of water pollution, as described by (11). The computation depends on the physicochemical data obtained through laboratory analysis of the collected water samples. The analysis results of the Comprehensive Pollution Index (CPI) value at each station are represented in (Figure 2). The seasonal CPI values for Sites 1 to 5 show variations within the range of 1.18 to 2.57 (in summer) and 0.86 to 1.53 (in winter). In accordance with the CPI rating scale, the pollution index values for both sites (S3 and S5) were found to exceed 2 during the summer season. This might be attributed to the discharge of sewage from the Sarchinar sewage outlet box into the Qiliasan stream through smaller sewer pipelines along the stream. Additionally, the discharge of substantial sewage effluent from multiple sources, including the Industrial area, Albisaka, Qalawa, Kostai-Cham, Awal, and Bakrajo boxes, could also be contributing factors. Based on the calculation of the Comprehensive Pollution Index (CPI), it is evident that all stations were categorized as having moderately to severely polluted water during the summer season. However, in the winter season, the water quality ranged from slightly to moderately contaminated (Table 2). As shown in Figure 2, the graphical representation clearly illustrates that the pollution level remained low at the upstream sites and was elevated at the downstream site during both the summer and winter seasons. This difference is attributed to the high activity in the downstream area and the potential impact of upstream activities, which can significantly alter the water conditions in these regions.

Table 4: Calculation results of Comprehensive Pollution Index (CPI) at all sites in winter and summer seasons.

Sites	CPI (winter)	CPI (summer)	Category
S1	0.86	1.18	The water quality was slightly contaminated in winter and moderately contaminated in summer.
S2	0.90	1.29	The water quality was slightly contaminated in winter and moderately contaminated in summer.
S3	1.36	2.57	The water quality exhibited moderate contamination in winter and severe contamination in summer.
S4	1.16	1.99	The water quality showed moderate pollution levels in both winter and summer.
S5	1.53	2.57	The water quality exhibited moderate contamination in winter and severe contamination in summer.

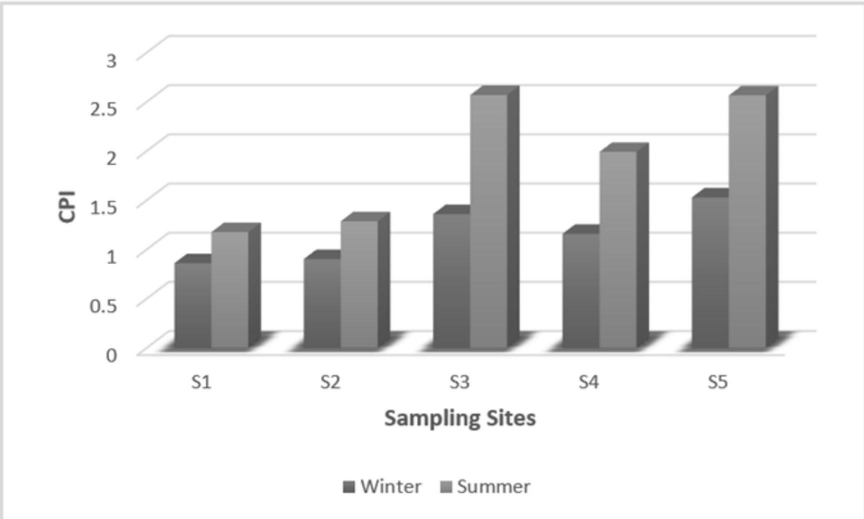

Figure 2: Variation of CPI during winter and summer.

Conclusions

After examining various parameters, the current study has determined that the physicochemical characteristics of the Qiliasan and Kani-Ban streams' water exhibit moderate to severe pollution during the summer season and slight to moderate contamination in the winter, as per the Comprehensive Pollution Index (CPI) classification. The Comprehensive Pollution Index (CPI) was observed to be greater in the dry season compared to the wet season, rendering it a more obvious pollution indicator during the dry season. This difference can be attributed to the fact that the water of the Qiliasan and Kani-Ban streams receives a larger amount of wastewater and agricultural waste during the dry season, leading to less dilution of water compared to the wet season. Hence, it is recommended that water quality should undergo treatment prior to use, and specifically, the treatment of wastewater before its discharge into the Qiliasan and Kani-Ban streams is advised.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Nizar Yaseen Hamah Saleh performed all tasks: methodology, writing—original draft preparation, and writing—review and editing. The author has read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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