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APPLICATION OF CCME-WQI IN SPATIAL AND SEASONAL EVALUATION OF WATER QUALITY OF KHABOUR RIVER, ZAKHO DISTRICT, KURDISTAN REGION OF IRAQ

IBRAHEM AHMED. HUSSEIN

Department of Environmental Science, Faculty of Science, University OF Zakho, Kurdistan Region-Iraq.
Email: Ibrahim.hussein@uoz.edu.krd

MUSTAFA ISMAIL UMER

Department of Soil and Water, College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region-Iraq. Email: Mustafa.umer@uod.ac

Abstract

This study focuses on the application of the Canadian model of Water Quality Index (CCME-WQI) for the spatial and seasonal evaluation of water quality of the Khabour River, within Zakho District, Kurdistan of Iraq. Khabour River serves as a vital water source for drinking, irrigation, and livestock needs in the surrounding communities. However, The River is being polluted as a result of diffuse sources like agricultural practices and the discharge of untreated sewage, causing detrimental effects. Six stations were chosen on Khabour River; water samples were collected monthly from March 2022 to February 2023, 19 parameters were analyzed to evaluate the water quality of the river. The results revealed that out of the 19 studied parameters, nine were within permissible limits, including electrical conductivity, total suspended solids, total dissolved solids, dissolved oxygen, pH, total hardness, total alkalinity, chloride, and nitrate. However, the remaining ten parameters, including turbidity, biochemical oxygen demand, calcium, magnesium, total phosphate, nickel, copper, lead, iron, and chromium, exceeded the permissible limits, indicating deteriorated water quality. According to the results, the water quality at all stations was determined to be "poor" during both the dry and wet seasons. The findings emphasize the need for effective water management strategies, pollution reduction and wastewater treatment to safeguard the Khabour River and ensure the availability of clean water resources for the local people.

Keywords: Water Quality, CCME-WQI, Kabour River, Zakho

1. INTRODUCTION

Water is one of the most vital resources for all life on Earth. While the planet is predominantly covered in water, only a small percentage of it is readily available for human consumption [1]. Currently, the potable water resources suffer from deterioration due to agricultural, industrial and civil activities, as well as the hydrological conditions and climate of each region [2]. Factors contributing to water scarcity include population growth, uneven distribution, climate change, pollution, and inadequate infrastructure [3]. Around 2.2 billion people worldwide lack access to safe drinking water, highlighting the gravity of the global water crisis [4]. The water resource within a river basin is influenced by several variables, including precipitation, soil conditions, land usage, as well as both natural and human-induced disasters [5]. Climate changes play a significant role in disrupting the equilibrium between the availability and demand of water resources at both regional and global scales [6], this impact can be clearly manifested as a severe drought or flood [7].

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Water pollution affects human health either directly, which may be psychologically by giving the water an unpalatable color, taste and smell, or it turns the water into a carrier of many bacterial, viral and parasitic pathogens that cause cholera, typhoid, shigellosis and viral infections such as hepatitis (A,E) as well as many parasitic infections like amoebiasis, giardiasis and toxoplasmosis [8, 9] or indirectly through the cumulative effect of heavy metals and toxic chemicals whose effect appears on humans after a period of time [10]. Governments, organizations, and individuals must work together to protect water sources, reduce pollution, and implement efficient water management strategies. Conservation efforts, such as rainwater harvesting, efficient irrigation systems, and public awareness campaigns, can contribute to preserving and maximizing the availability of potable water [11].

The Khabour River suffers from non-point pollution, represented by erosion and washing of agricultural lands on both banks of the river outside the city, which causes turbidity to reach undesirable levels as well as addition of fertilizers that affect the water quality [12]. Inside the city untreated municipal sewage is collected through the sewers and discharge into the Khabour. This water contains human wastes, detergents, soap, cooking oils, chemicals and also adds a lot of pathogens to the river [13]. Rivers get rid of waste through self-purification, which depends on several factors, including dilution, current, and rate of oxidation, reduction, temperature, sedimentation and hydrography [2]. In the current study, the fifth and sixth stations were chosen away from the city to investigate the river's ability to self-purify.

To demonstrate the quality of water, various approaches and techniques have been created; one of these methods is the water quality index WQI, which integrates many physio-chemical and biological variables to estimate the water quality [14]. Some models have been developed for specific areas, and some are specific to certain factors, such as National sanitation foundation water quality index (NSFWQI), which depends on only 9 factors like pH, dissolved oxygen, biochemical oxygen demand, nitrate, total phosphate, turbidity, temperature and feacal coliform. One of the most popular models in many countries is the Canadian model CCME-WQI which developed by Canadian Council of Ministers of the Environment, because of its ability to accurate evaluation of the overall water condition. The Canadian model used on various water bodies, especially rivers. This model has several advantages, the most important of which is that different standards can be adopted. The second advantage is that an unlimited number of factors can be used. It also has the ability to give explanations in the absence of some data [15, 16] .This method was used in many countries of the world such as Iraq [17], India [18], Indonesia [2] and Romania [19]. So, the aim of current study is to apply CCME-WQI in spatial and seasonal assess of water quality of the Khabur River in Zakho district for first time.

2. METHODS AND MATERIALS

2.1 Methodology

The study was done on Khabour River, Zakho district, Kurdistan Region of Iraq. Table: 1. The Khabour River originates in the Eastern Anatolia Region of Turkey, travels southward Flowing across the Turkey-Iraqi border and then subsequently heads westward, As it passes through

Zakho City, the river eventually merges with the Tigris River, In close vicinity, just southward, the length of Khabour River is 181 km and The average annual flow rate of the Khabour River is 68 m3/sec [20]. Approximately 60% of the total precipitation, which includes snowfall, happens during the winter season, while around 25% takes place in spring. In the fall season, rainfall accounts for 14% of the total precipitation, while during summer, rainfall contributes merely 1% of the overall precipitation. The Khabour River displays a distinct seasonal flow pattern, characterized by a peak in May and a relatively lower flow from July to December [21]. Khabour River serves as a crucial water source for drinking, irrigation, and livestock needs of the communities residing in its vicinity [22].

Six stations were selected for the study on the Khabour River within Zakho district; figure: 1.The study covered about 30 km of the river, started from Tawke village (first station) and extends to Bachuk village (sixth station). The first station is about 11 km away before the river enters the city and was considered as a control point, it surrounded by agricultural lands on both sides of the river.

The second, third and fourth stations are located inside the city; here sewers discharge sewage water directly to the river. The fifth station is about 5 km away from the city and there are quarries for the production of gravel and sand. The Sixth Station, located about 15 km from the city center, on the Iraqi-Turkish border, and is characterized by the presence of agricultural lands on the both river bank, this station was chosen to know the ability of the river to self-purify from the pollutants that it suffers from the civil activation within the city.

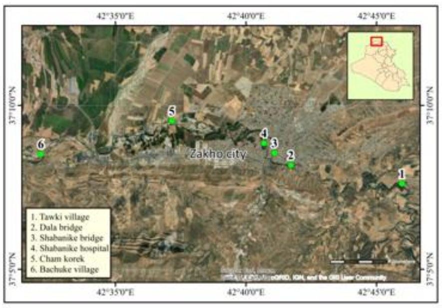

Figure 1: Map of studied area

Table 1: Geographic distribution of studied stations

St	Location	Altitudes (N)	Longitudes (E)
1	Tawki village	37.126904	42.766273
2	Dalal bridge	37.136246	42.696153
3	Shabanike brige	37.145065	42.680746
4	Shabanike hospital	37.145156	42.680981
5	Cham korek	37.158812	42.619264
6	Bachuk village	37.141944	42.535671

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2.2 SAMPLING

The study period extended from March 2022 to February 2023, 19 parameters were chooses to be studied, and samples were collected monthly from the sixth stations in clean polyethylene bottles for physical and chemical examinations. special glass bottles of 250 ml capacity is were used for DO and BOD samples, samples of total phosphate testing were collected in glass bottles, and the tests were carried out according to [23], all methods and instruments used in the measurements of aforementioned parameters are summarized in table 3.

2.3 CCME-WQI CALCULATING

The index is determined by taking into account a blend of three factors:

F1 (Scope) represent the count of parameter which fall to meet the standards (failed tests),

$$F1=\left[\frac{\text{Number of failed varables}}{\text{Total numbers of variables}}\right]\times 100$$

F2 (Frequency) with which the objectives are not achieved,

$$F2=\left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right]\times 100$$

F3 (Amplitude) is the degree to which the objectives fall short; it is calculated in three steps:

i. The count of occurrences where an individual concentration exceeds (or falls below, in the case of a minimum objective). The objective is referred to as "excursion". When the measured

Value should not exceed the target limit: $\text{excursion}_i=\left[\frac{\text{Failed Test Valuei}}{\text{Standard value}}\right]-1$

In situations where the parameter value should not dip below target limit:

$$\text{excursion}_i=\left[\frac{\text{Standard value}}{\text{Failed Test Valuei}}\right]-1$$

ii. The normalized sum of excursions, or nse, so nse is computed as:

$$\text{nse}=\frac{\sum_{i=1}^{n}\text{excursion}}{\text{number of tests}}$$

F3 is subsequently computed using the following equation:to convert (nse) into a range between 0-100.

$$F3=\frac{\text{nse}}{0.01\text{nse}+0.01}$$

Finally, the three factors (F1, F2 and F3 are merged to generate an individual value (ranging from 0-100) that characterizes the quality of water as shown in the table 2.

$$\text{CCME-WQI}=100-\frac{\sqrt{F1^2+F2^2++F3^2}}{1.732}$$

Table 2: CCME-WQI categories [2]

CCME-WQI	Water state
0-44	Poor
45-64	Marginal
65-79	Fair
80-94	Good
95-100	Excellent

3. RESULTS AND DISCUSSION

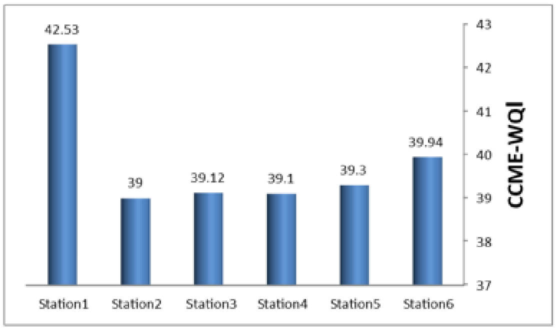
The spatial and temporal water quality of the six stations on the river was determined using the CCME-WQI. The Canadian model can aggregate and transferred a huge number of data into individual numbers, which facilitate understanding of the suitability of water for human use.

Due to the flexibility of the Canadian model in the use of standards, two types of standards belonging to the WHO [25] and the Iraqi standard for drinking water quality [26] were used in the current study, see table 3.

Among the nineteen studied parameters, it was noted that nine of them had values within the permissible limits, and these parameters were EC, TSS, TDS, pH, DO, TA, TH, Cl, NO3, While the remaining ten parameters: Turbidity, BOD, Ca, Mg, TP, Ni, Cu, Pb, Fe, Cr were exceeded the permissible limits spatially and temporally, which led to a decrease in the values of the water quality scale, and thus the deterioration of the river water quality. Phosphates are essential nutrients that play a crucial role in supporting various biological processes in aquatic ecosystems. However, excessive levels of phosphate in rivers can lead to eutrophication and oxygen depletion [27]. Calcium plays a vital role in nutrient cycling, buffering pH levels, and providing structural support to aquatic organisms [28]. Magnesium affects water quality, nutrient availability, and the overall health of aquatic ecosystems. And these elements are released into rivers naturally from many sources like the weathering of rocks, erosion of soil, Organic Matter Decay [29], Agricultural Runoff (fertilizers), untreated wastewater Discharge, Construction and Land Development, Urban Runoff and Industrial Activities [30].

Heavy metals such as Iron (Fe), Nickel (Ni) Lead (Pb), Copper (Cu) and Chromium (Cr) are widespread contaminants in rivers, posing significant risks to human health and the environment. The sources of these metals includes mining, Industrial Effluents, Agricultural Practices (fertilizers, pesticides, and animal manure) [30], Urban Runoff and Stormwater [31]. It is noted from the figures (2, 3, 4 and 5) that the river water in all stations during the four seasons was classified as ″poor″ category (Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels) [26], and this is due to the volume of pollutants that were thrown into the river before entering the city and inside the city.

It is also observed from the Previous figures that the river water in the first station (upstream) was slightly better, and the sources of pollution in it may be due to the washing of agricultural lands during rain storms, which leads to the drainage of fertilizers to the river because agricultural activities occupy around 23% of the river basin [32] . The deterioration of the river water quality inside the city increased in the third and fourth stations due to their nearby to location of sewage water.



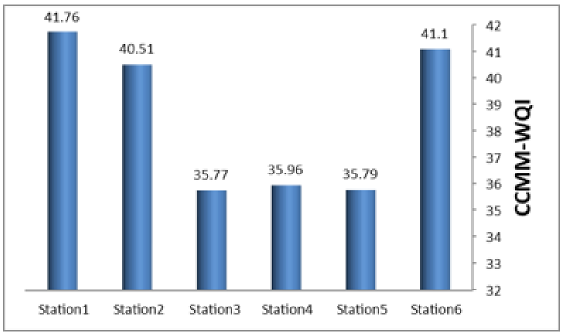
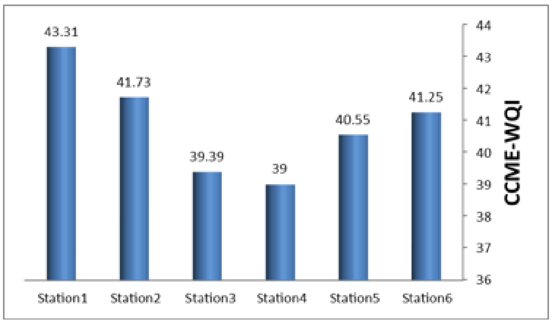


Figure 2: CCME-WQI in the Spring **Figure 3: CCME-WQI in the summer**



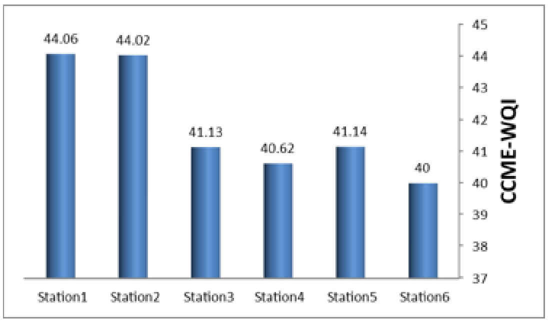


Figure 4: CCME-WQI in the Autumn **Figure 5: CCME-WQI in the winter**

Table 3: A summary of descriptive statistical of studied parameters (measured in mg/L except EC in mS/cm, Turbidity in NTU, pH in pH unit), and of Khabour River, in six stations for 12 months

Parameters + (abbreviation)	Maxi.	Mini.	Annual Mean	S. deviation	+ S. Error	Standards	Instrument & Methods
Electrical Conductivity (EC)	541	400	466.17	42.12	4.96	1000	Five Easy FE30 EC meter
Total Suspended Solids TSS)	0.198	0.11	0.092	51.75	6.09	20	Dried oven at 105° C
Total Dissolved Solids (TDS)	379	280	326.31	29.47	3.47	500	TDS meter HI 99301
Turbidity	171	1.37	24.43	40.66	4.79	5	Turbidity meter AL25
Hydrogen Ion (pH)	8.47	7	7.80	0.40	0.04	6.5-8.5	Five Easy FE20 pH meter
Dissolved Oxygen (DO)	8.9	5.6	7.34	0.73	0.08	5	Azide Modification
Bio. Oxygen Demand (BOD)	4.5	0.6	2.39	0.95	0.11	3	Azide Modification

Total Alkalinity (TA)	190	120	153.54	17.96	2.11	200	EDTA Titrimetric Method
Total Hardness (TH)	320	154	235.18	41.04	4.83	500	EDTA Titrimetric Method
Calcium (Ca)	162	100	132.27	13.16	1.55	75	EDTA Titrimetric Method
Magnesium (Mg)	180	42	102.90	34.03	4.01	50	EDTA Titrimetric Method
Chloride (Cl^-)	28	12	20.51	3.93	0.46	250	AgNO3 Titration Method
Nitrate (NO_3)	3.15	0.24	0.96	0.62	0.07	50	Phenoldisulphonic Method
Total Phosphate (TP)	1.293	0.03	0.29	0.09	0.01	0.2	Stannous Chloride Method
Nickel (Ni)	1.071	0.02	0.45	0.31	0.03	0.07	Atomic Absorption
Cupper (Cu)	0.112	0	0.05	0.03	0.003	1	Atomic Absorption
Lead (Pb)	2.016	0	0.86	0.69	0.08	0.01	Atomic Absorption
Iron (Fe)	0.931	0	0.44	0.35	0.04	0.3	Atomic Absorption
Chromium (Cr)	0.295	0	0.07	0.09	0.01	0.05	Atomic Absorption

4. CONCLUSION

Despite the planet's abundance of water, only a small portion is readily available for human consumption. The deterioration of The Khabour River resources is attributed to various factors such as agricultural, industrial, and civil activities, as well as hydrological conditions and climate.The overall water quality of the river was categorized as "poor," indicating a significant degradation caused by pollutants discharged into the river before and within the city. The study also identified the limited self-purification capacity of the river, due to the small size of the river basin compared to the volume of pollutants. The research emphasizes the need for the Zakho government to take action by implementing sewage treatment strategies and raising public awareness about proper waste disposal to protect the river.

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