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Evaluating the suitability of water in border tributaries of The Diyala's River Basin for various purposes

Abdulmutalib Raafat Sarhat[1,*]

[1]University of Garmian, Collage of Science, Chemistry Department, Kalar, Sulaymaniah, Iraq.

* Corresponding Author E-mail :abdulmutalib.raafat@garmian.edu.krd

Abstract

This research aimed to examine the water quality of some international tributaries within Diyala River Basin that originate from Iran. Diyala River and its tributaries plays a significant role in providing water for manufacturing, irrigation and domestic purposes for large part of Sulaymaniyah and Diyala Province. Recently, this river and its tributaries (Sirwan, Alwand, Qurato, Hawasan and Zmkan) have suffered from increasing pollution, due to decreasing their flows from Iran as a result of constructing many dams and irrigation projects, as well as changing the course of some of them into Iran. Also, wastes from domestic sewage, industries and agricultural activities are discharging directly into Diyala River and its tributaries without treatment, and then causes deterioration of water quality in large scale. Investigating the tributaries of Diyala River is very important to implement a study for understanding the quality of waters that flow into it. Water Quality Index (WQI) was utilized to describe the quality level of water in the observed tributaries. Some chemical characterization: pH, EC, TH, NO3, DO and F- of water samples were analyzed to calculate the value of WQI at each tributary. Based on the overall values of WQI, waters in all the monitored tributaries are not suitable for drinking purpose; while, most of them are acceptable for irrigation purpose. Water quality was found (Unsuitable/Proper treatment required) only in Alwand Tributary.

Keywords: Diyala River, Border Tributaries, Water Quality Index, Pollution

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تقييم مدى صلاحية مياه الروافد الحدودية لحوض نهر ديالى للأغراض المختلفة

عبد المطلب رأفت[1]*

[1] جامعة كرميان، كلية العلوم، قسم الكيمياء، كلار، السليمانية، العراق.

*ايميل المؤلف المرسل: abdulmutalib.raafat@garmian.edu.krd

الخلاصة

يهدف هذا البحث إلى دراسة نوعية المياه لبعض الروافد الدولية ضمن حوض نهر ديالى والتي تنبع جميعها من إيران. يلعب نهر ديالى وروافده دوراً هاماً في توفير المياه لأغراض الصناعة والري والأغراض المنزلية لجزء كبير من محافظة السليمانية وديالى. ومنذ فترة معينة يعاني هذا النهر وروافده (سيروان، الوند، قورةتو، هواسان، زمكان) من تلوث متزايد، بسبب انخفاض تدفقاته من إيران نتيجة لإنشاء العديد من السدود ومشاريع الري، فضلاً عن تغيير مجاري بعض منها إلى داخل إيران. كما أن النفايات الناتجة عن الصرف الصحي المنزلي والصناعات والأنشطة الزراعية تصب مباشرة في نهر ديالى وروافده دون معالجة، مما يؤدي إلى تدهور نوعية المياه على نطاق واسع. إن دراسة روافد نهر ديالى مهمة جداً لإجراء دراسة لفهم نوعية المياه التي تتدفق فيه. تم استخدام مؤشر جودة المياه (WQI) لوصف مستوى جودة المياه في الروافد المرصودة. وقد تم تحليل بعض المعايير الفيزيائية والكيميائية ومنها (pH، EC، TH، NO3، DO وF-) لعينات المياه لحساب مستوى جودة المياه (WQI) لكل رافد. استناداً إلى القيم الإجمالية لمؤشر نوعية المياه، فإن المياه في جميع الروافد لم تكن مناسبة لأغراض الشرب؛ في حين أن معظمها مقبول لأغراض الري. وقد تم العثور على نوعية مياه (غير مناسبة/مطلوب معالجة مناسبة) فقط في رافد الوند.

الكلمات المفتاحية: حوض نهر ديالى، الروافد الحدودية، مؤشر جودة المياه، التلوث.

1. Introduction

Water is considered as an essential source for the human survival and for the global economy. Fundamental human right lies in the availability of water and easy access to safe quality of water (Luvhimbi et al., 2022). While, due to the influence of both anthropogenic and natural factors; the quality of water around the world has rapidly declined (Vadde et al., 2018) (Son et al., 2020). Evaluating the quality of water for various purposes are a significant approach for human health and food security (Goonetilleke et al., 2007). Also, the assessment of water quality aims to investigate the sources of pollution and then improve an approach for managing water resources sustainably (Gaur et al., 2022) (Khadija et al., 2021). The chemical, physical and biological characteristics of water are used as parameters in order to describe and evaluate its quality and then determine its suitability for different uses (Hubert and Wolkersdorfer 2015).

A major concern all over the world is the increasing of water pollution as a consequence of anthropogenic activity, and it is one of the most significant issues that threaten the environment (Abah et al., 2016). Developing countries lack stringent measures that prevent wastewater from being discharged into water bodies (Ebsa and Kabeta 2022). Approximately 80% of wastewater around the world discharges back into lakes, rivers, and oceans. Pollution affects the quality of water and then transfers its harmful substances to humans and the environment (Abdulrazzak et al., 2020). Therefore, assessment of water quality is essential in developing countries due to their vulnerability to pollution and extreme demand.

In the past, comparing the value of each parameter in a water sample to the permissible value of the same parameter was the best way to judge water quality. Nowadays, a number of indices regarding water quality have been introduced and developed by researchers around the world. Water quality index based on weighted arithmetic index method is an effective tool to monitor the quality of water and forward the information to the decision makers and the concerned citizens. Moreover, WQI is considered as one of the most influential means that is utilized to monitor water quality. Also, it is a number of standards that is utilized to measure changes in the quality of water in a certain water source over time, and it allows making comparisons between various water sources.

In the last few years, Iraqi water resources have suffered from unusual stress regarding water quantity as a result of dam constructions on the rivers and tributaries in the riparian countries (A. Sarhat 2022). Moreover, the increase in population and the climatic changes has led to a decrease in the rate of annual precipitation and water shortage (A. Sarhat 2022) (Toma 2012). The Diyala River Basin includes a number of international tributaries that originate from Iran. These tributaries include: Sirwan, Zamkan, Hawasan and Qurto, within the Sulaymaniyah Governorate; in addition to The Alwand Tributary within Diyala Governorate. Iran has proceeded to construct water projects and dams on the international tributaries along the border with Iraq. Tropical Water Project (TWP), in Iran, is a significant project that has been constructed recently on Diyala's River Basin, which aims to increase irrigated lands. Ultimately, this has caused water shortage which resulted in an increase in the proportion of pollutants in the Diyala's River Tributaries.

The aim of this study is to examine the water quality of some international tributaries within Diyala's River Basin that originate from Iran, by utilizing WQI.

2. Materials and Methods

2.1. Study area

The Diyala River Basin contains a number of tributaries, which include: The Sirwan, Zamkan, Hawasan and Qurto within the Sulaymaniyah Governorate, as well as the Alwand tributary within Diyala Governorate, which are all international tributaries and originate from Iran, Fig.1.

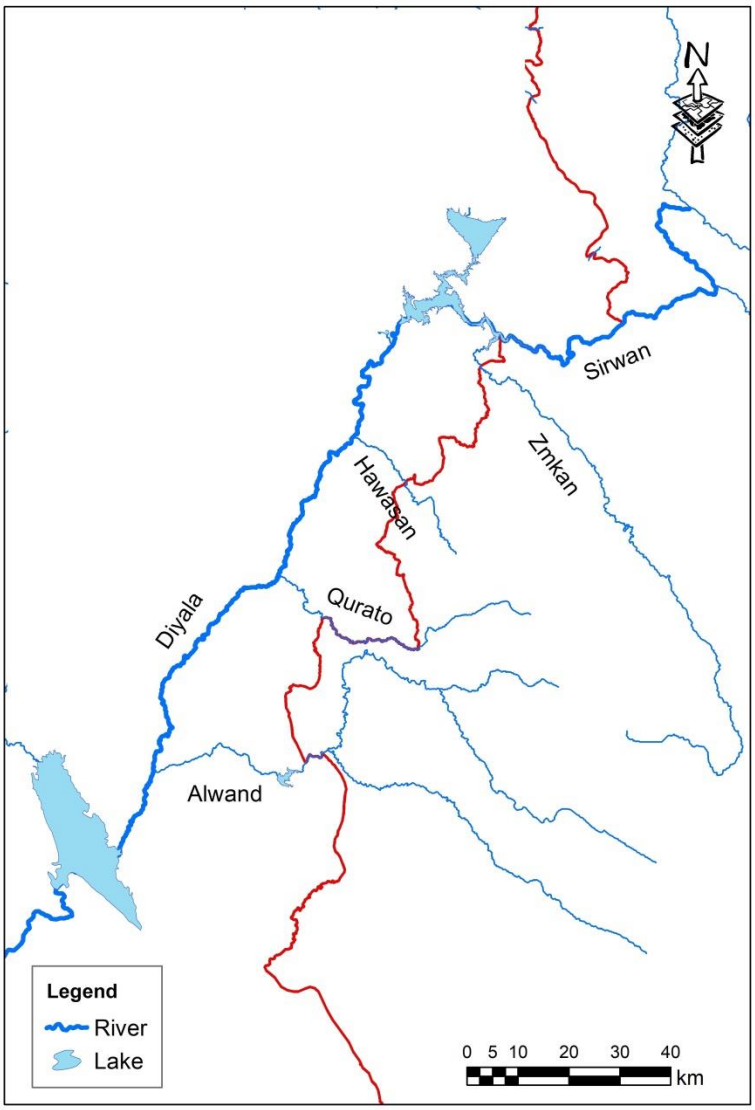

Fig 1: The study area

2.2. Sampling

Six random samples were collected from each tributary, at a depth of 30 cm. They were collected during the dry seasons (June – August) 2023. All the samples were stored at 20 ^{o}C in a laboratory. The EC, pH and DO were immediately measured on-site, while the parameters were not measured on-site (NO_3, TH and F^-) were analysed within 24 hours.

2.3. Samples analysis

Table (1) shows the used devices and the followed methods to determine the chemical parameters.

Table (1): The devices and methods used in measuring the chemical parameters

NO.	Parameter	Method/Device
1	pH	Portable pH meter (HANNa HI 2211)
2	EC	HI-9829 multi-parameter EC meter
3	DO	DO probe: A HI-98198
4	NO3	Ion Selective Electrode ISE
5	TH	Titration/ by using K10 buffer with EDTA solution and (Erichrome Black) indicator
6	F-	Ion Selective Electrode ISE

2.4. Determination of WQI

Six parameters were analysed in order to determine the suitability of water in the study area for industrial, irrigation and drinking purposes based on some standards. The examined parameters include (EC, pH, NO_3, DO, TH and F^-). The method of weighted arithmetic index (Chatterjee and Raziuddin 2002) (Brown et al. 1972) was utilized to calculate WQI by using the following formula:

$$WQI = \sum_{i=1}^{n} W_i * q_i / \sum_{i=1}^{n} W_i \quad (1)$$

Where, (WQI) represents Water Quality Index; (Wi) is the weight unit for each parameter (nth); (qi) is the quality rating, which was calculated by the following formula:

$$q_i = 100[\frac{(V_i - V_{id})}{S_i - V_{id}}] \quad (2)$$

Where, (i) represents each parameter; (Vi) is the determined value of each parameter (nth); (Si) represents the permissible value of each parameter. (Vid) represents the ideal value of each parameter. Zero was set as ideal value for the parameters except DO and pH which set as 14.6 and 7 respectively:

$$q_{pH} = 100[(V_{PH} - 7.0) / (8.5\text{-}7)] \quad (3)$$

$$q_{DO} = 100[(V_{DO} - 14.6) / (5\text{-}14.6)] \quad (4)$$

The Table (2) and (3) show the water quality index (WQI) value and the level of determined water quality status based on Weighted Arithmetic Index WAI;

Table (2) : Values and status of (WQI) based on WAI (Chatterjee and Raziuddin 2002) (Brown et al., 1972).

WQI	Status	Possible Usage
0-5	Excellent	Domestic, Industrial and Irrigation
26-50	Good	Domestic, Industrial and Irrigation
51-75	Poor	Industrial and Irrigation
76-100	Very poor	Irrigation
Above 100	Unsuitable	actual treatment is desired before use

Table (3) : Weights of the WQI Parameters (ISQ 2001) (Herschy 2012) (Tyagi et al., 2020) (WHO 2018)

Parameters	ISQ and WHO Standard	Weight
pH	8.5	0.12
EC	600	0.0017
NO3	50	0.02
TH	500	0.002
DO	14.6	0.2
Fluoride	1.5	0.67
Total		**1**

3. Results and discussion

3.1. Chemical characterization

Table (4) shows the chemical characteristics of the tributaries water samples. The results show that the pH value ranged between 7.49 and 8.1 in Sirwan Tributary, 7.98 and 8.72 in Alwand Tributary, 7.45 and 8.48 in Qurato Tributary, 7.91 and 8.76 in Hawasan Tributary, and 7.56 and 8.91 in Zmkan Tributary. Also, the average values of pH were 7.91, 8.26, 8.01, 8.24 and 8.32 in Sirwan, Alwand, Qurato, Hawasan and Zmkan Tributaries, respectively. The pH values of the studied tributaries are slightly alkaline, as the water resources in the northern parts of Iraq tend to be slightly alkaline (Ewaid 2017). However, the obtained values of pH in some sample stations within Alwand, Hawasan and Zmkan tributaries were in the highest permissible ranges of ISQ and WHO standards.

The ranges of EC in the studied tributaries were 508-788, 974-2053, 859-1267, 956-1460, and 590-975 $\mu s.cm^{-1}$ with averages of 652.67, 1675.66, 1136, 1145.5, and 719.83 $\mu s.cm^{-1}$ in Sirwan, Alwand, Qurato, Hawasan and Zmkan Tributaries, respectively. Based on the results, the water samples of the studied tributaries show increase in EC especially in Alwand, Hawasan and Qurato. The values of EC increased along the tributaries paths as a result of decreasing water flows from Iran and discharging large amounts of wastewater from various sources, which contain high quantities of dissolved salts.

The concentrations range of DO were 6.7-10, 4.78-6.33, 4.88-5.8, 4.13-5.25 and 4.34-5.65 $mg.L^{-1}$, with averages of 8.57, 5.52, 5.29, 4.79 and 5.01 $mg.L^{-1}$ in Sirwan, Alwand, Qurato, Hawasan and Zmkan Tributaries, respectively. The results revealed that the concentrations of DO at the upstream of tributaries except Qurato were higher than those of the DO concentrations in the downstream, due to deteriorating the quality of water in the downstream parts.

The level of total hardness in most of the sampling stations in Alwand, Qurato and Hawasan tributaries exceeded 500 $mg.L^{-1}$. The average values of total hardness were 398.37, 693.58, 489.07, 515.47 and 494.32 $mg.L^{-1}$, in Sirwan, Alwand, Qurato, Hawasan and Zmkan Tributaries, respectively. This indicates that the content of TH tend to be high throughout the studied area. The increasing of TH in Iraqi water resources might cause by the nature of soils which are rich in calcium carbonate (Ali et al., 2023).

The depletion of dissolved oxygen in water is caused by the presence of nitrate which stimulates algae and undesirable aquatic growth. Nitrate is considered as one of the major pollutant in water, and water with concentrations of nitrate above 50 $mg.L^{-1}$ regarded as unsuitable for domestic purpose (Brindha et al., 2017). However, domestic water with concentration of nitrate above 10 $mg.L^{-1}$ may cause immediate health issues for infants (Ward, et al., 2018). The concentrations of more than 50% of the sampling stations in Qurato and Hawasan Rivers were above 10 $mg.L^{-1}$.

Every water resource contains fluoride in various concentrations. However, the level of fluoride in water is not sufficient to protect tooth from decay (Aoun et al., 2018). The ideal concentration of fluoride in drinking water should not be less than 1 $mg.L^{-1}$ (Sarhat et al., 2023) (Akter et al., 2016); however, the level of F^- in all the sample stations in the study area were less than 0.5 $mg.L^{-1}$.

Table (4): The range values of chemical characterizations for water at studied areas

Tributaries		pH	EC	NO_3	TH	DO	F^-
Sirwan	Min.	7.49	508	4.1	386.28	6.7	0.37
	Max.	8.1	788	8.1	412.39	10	0.44
	Ave.	7.91	652.67	5.60	398.37	8.57	0.41
	St.D	0.224	101.28	1.74	11.66	1.28	0.025
Alwand	Min.	7.98	974	5.1	518.3	4.78	0.23
	Max.	8.72	2053	10.2	867.35	6.33	0.61
	Ave.	8.26	1675.33	7.59	693.58	5.52	0.4
	St.D	0.295	383.07	2.04	134.87	0.61	0.13
Qurato	Min.	7.45	859	5.21	458.44	4.88	0.33
	Max.	8.48	1267	12.12	528.34	5.8	0.44
	Ave.	8.01	1136	9.27	489.07	5.29	0.39
	St.D	0.346	167	2.63	23.78	0.355	0.039
Hawasan	Min.	7.91	956	8.94	457	4.13	0.3
	Max.	8.76	1460	12.64	569.4	5.25	0.47
	Ave.	8.24	1145.5	10.59	515.47	4.79	0.405
	St.D	0.324	195.75	1.39	37.36	0.49	0.058
Zmkan	Min.	7.56	590	4.88	483	4.34	0.29

	Max.	8.91	975	10.67	503	5.65	0.44
	Ave.	8.32	719.83	8.34	494.32	5.01	0.37
	St.D	0.52	139.34	2.25	8.45	0.55	0.05

3.2. Evaluation of WQI

As shown in Table 5 and 6, the observed ranges of WQI were 48.45–60.499, 87.18-120.31, 77.9-90.1, 79.23-96.23 and 67.06-81.78 with averages of 55.11, 105.09, 79.9, 86.45 and 73.69 for Sirwan, Alwand, Qurato, Hawasan and Zmkan Tributaries, respectively.

Table (5) : The values and status of WQI at studied tributaries

Tributary	**Parameter**	**Observed Values**	**Unit Weight (W_a)**	**Quality Index (Q_n)**	**$W_n Q_n$**	**WQI**	**Ave. WQI**	**Possible Usage**
Sirwan	pH	7.91	0.12	41	4.82	41	55.11	Irrigation and Industrial
	EC	652.67	0.00	109	0.18	108.78		
	NO_3	5.60	0.02	11	0.22	11.20		
	TH	398.37	0.00	80	0.159	80		
	DO	8.57	0.20	63	12.56	63		
	F^-	0.41	0.67	27	18.148	27.2		
Alwand	pH	8.26	0.12	76	8.96	76.17	105.09	Proper treatment required
	EC	1675.33	0.00	279	0.47	279.22		
	NO_3	7.59	0.02	15	0.30	15.18		

	TH	693.58	0.00	139	0.277	139		
	DO	5.52	0.20	95	18.92	95		
	F^-	0.40	0.67	27	17.778	26.7		
Qurato	pH	8.01	0.12	51	5.94	50.5	79.9	Irrigation
	EC	1136.00	0.00	189	0.32	189.33		
	NO_3	9.27	0.02	19	0.37	18.53		
	TH	489.07	0.00	98	0.196	98		
	DO	5.29	0.20	97	19.40	97		
	F^-	0.39	0.67	26	17.481	26.2		
Hawasan	pH	8.24	0.12	74	8.75	74.33	86.45	Irrigation
	EC	1145.50	0.00	191	0.32	190.92		
	NO_3	10.59	0.02	21	0.42	21.18		
	TH	515.47	0.00	103	0.206	103		
	DO	4.79	0.20	102	20.44	102		
	F^-	0.41	0.67	27	18.000	27.0		
Zmkan	pH	8.32	0.12	82	9.67	82.17	73.69	Irrigation and Industrial
	EC	719.83	0.0017	120	0.20	119.97		
	NO_3	8.34	0.02	17	0.33	16.68		

	TH	494.32	0.002	99	0.198	99		
	DO	5.01	0.2	100	19.98	100		
	F^-	0.37	0.67	25	16.370	24.6		

Table (6) : The values and status of WQI at studied tributaries

Tributaries	Values			Status
	Min.	Max.	Ave.	
Sirwan	48.45	60.499	55.11	Poor
Alwand	87.18	120.31	105.09	Unsuitable
Qurato	77.9	90.1	79.9	Very poor
Hawasan	79.23	96.23	86.45	Very poor
Zmkan	67.06	81.78	73.69	Poor

According to the overall values of WQI, the water in all the monitored tributaries are not suitable for drinking purposes; however, the water in most of the tributaries are acceptable for irrigation purposes. As shown in Table 5, water quality was found to be under unsuitable category only in Alwand Tributary due to the high values of chemical parameters which contributes to the high composite impact on water quality.

The deterioration of water quality in the studied tributaries was due to the decrease in water flow from Iran as a result of constructing a number of dams and irrigation projects on these tributaries, and changing the course of some of them into Iran. Moreover, the inputs of industrial, municipal, and agricultural wastes discharge into the tributary banks.

Some limitations were observed in this study. The samples were collected only during dry season; while, it would be better to collect samples during wet season too.

4. Conclusion

The water quality index based on weighted arithmetic method was utilized to some border tributaries including: Sirwan, Zamkan, Hawasan, Qurto and Alwand tributaries. According to the obtained WQI values, majority of the sampling stations have (Poor) to (Very poor) quality of water. Higher values of EC and TH, as well as lower values of DO and F^- have reduced the water quality. The result of this investigation showed that water quality of the observed tributaries was influenced by the projects that have been constructed in Iran and then have led to decrease water flows. Also, the activities that occur along the tributaries watersheds have significant impacts on their water quality.

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