



Comparative Analysis of Standard Water Quality Indices for Monitoring Northern Iranian Rivers: A Case Study of the Tajan, Haraz, and Cheshmekileh Rivers in Mazandaran Province



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ABSTRACT

Background: Water quality is increasingly threatened by human activities and the impact of climate change. In this study, the water quality of the Haraz, Tajan, and Cheshmeh Kileh Rivers in Mazandaran Province was evaluated using three widely recognized and reliable water quality indices.

Methods: Physicochemical data obtained from samples collected at specified stations during 2021 and 2023 were analyzed. The evaluated parameters included dissolved oxygen, biochemical oxygen demand, pH, turbidity, nitrate, phosphate, temperature, total coliforms, and total dissolved solids.

Results: The results demonstrated that the National Sanitation Foundation Water Quality Index (NSFWQI) and Iranian Water Quality Index (IRWQI) generally classified the water quality of the Haraz, Tajan, and Cheshmeh Kileh Rivers as Moderate to Good, whereas the British Columbia Water Quality Index (BCWQI) categorized several stations as falling within the Poor category. This outcome is consistent with findings from national and international studies, which indicate that the BCWQI tends to be more stringent and sensitive to deviations from established water quality standards.

Conclusion: A comparison of the present study with domestic and international research validates the reliability of the results and confirms that the observed differences among the indices (especially the greater sensitivity of BCWQI) are fully consistent with global observations. These similarities indicate that the use of the Water Quality Index (WQI) in surface water studies can well reflect spatial and temporal changes in river water quality in humid regions with a temperate climate, such as Mazandaran Province.

1. Introduction

Water is an essential and irreplaceable resource within environmental, economic, and social systems globally. As the global population continues to grow rapidly, along with urbanization, industrialization, and climate change, the demand for water resources has markedly increased. Surface water bodies, including rivers, serve as vital sources for drinking, agriculture, industry, and the sustainability of

ecosystems (Uddin et al., 2021; Das, 2024; Chidiac et al., 2023; Abbasi & Abbasi, 2012; Muniz & Oliveira-Filho, 2023; Deljomanesh et al., 2025; Gholami Deljomanesh et al., 2025).

Nonetheless, increased human activities, such as industrial waste, agricultural runoff, and the release of untreated sewage, have negatively affected the water quality in numerous rivers, posing risks to public health and biodiversity. As a result, continuous and systematic monitoring is crucial for identifying pollution sources and



supporting the sustainable management of water resources (Chidiac et al., 2023; Akhtar et al., 2021; Barroso et al., 2024; Mokuolu et al., 2023; Islami et al., 2022; Mohammadi et al., 2021; APHA, 1926).

To streamline the complex assessment of multiple water quality parameters, a range of Water Quality Indices (WQIs) (Luo et al., 2024; Aazami et al., 2015; Abbasi & Abbasi, 2012) has been established worldwide. These indices amalgamate various physical, chemical, and biological parameters into a single numeric value that reflects the overall water quality. Notably, the National Sanitation Foundation Water Quality Index (NSFWQI) (Brown et al., 1970), the Iranian River Water Quality Index (IRWQI) (Roshani-Sefidkouhi et al., 2025), and the British Columbia Water Quality Index (BCWQI) (WATER, 2001) are among the most acknowledged.

Numerous international studies have employed these indices to evaluate and compare the quality of river water across various spatial and temporal dimensions (Uddin et al., 2021; Chidiac et al., 2023). In Iran, while certain research has utilized individual indices for specific rivers, extensive comparative studies that apply multiple indices concurrently are still scarce (Aazami et al., 2015; Zamani-Ahmadmoodi et al., 2025).

This research seeks to address this deficiency by utilizing the NSFWQI, IRWQI, and BCWQI indices simultaneously to assess the surface water quality of three significant rivers in Mazandaran Province-Tajan, Haraz, and Cheshmeh Kileh-based on physicochemical data collected from 2021 and 2023. The research delivers a spatial and temporal evaluation of water quality, providing essential insights for environmental managers and policymakers.

2. Materials and Methods

2.1 Study Area

Mazandaran Province is situated in the northern part of Iran, adjacent to the southern shore of the Caspian Sea. It is recognized for its moist climate, plentiful precipitation, and diverse ecosystems, rendering it one of the most fertile and ecologically significant areas in Iran (Roshani-Sefidkouhi et al., 2025).

The province is characterized by an intricate system of rivers and streams, among which the Haraz, Tajan, and Cheshmeh Kileh Rivers serve as the primary surface water resources, significantly contributing to agricultural irrigation, drinking water supply, fisheries, and ecological preservation (Figure 1).

This research was carried out to assess the water quality of three significant rivers: Haraz, Tajan, and Cheshmeh Kileh, located in Mazandaran Province, northern Iran. Water samples were gathered from designated monitoring stations during 2021 and 2023 to offer a spatial and temporal depiction of water quality.

2.2 Tajan River

The Tajan River (Table 1) begins in the southeastern elevations of Sari County, traversing the Dodangeh and

Chahardangeh mountain ranges at altitudes ranging from about 2,600 to 3,300 meters above sea level. It features two main tributaries-Dourankeh (commonly referred to as the White River) and Chahardangeh-which meet at Rig Cheshmeh (Roshani-Sefidkouhi et al., 2025).

The river basin encompasses an area of roughly 4,147.22 km², while the primary river channel extends approximately 151.57 km in length, featuring an average gradient of 0.85%. The river predominantly flows from the southwest towards the northeast.

Significant tributaries consist of Chahardangeh, Khorramabad, Rudbar, and Sefidrud. The Tajan River serves multiple purposes, such as providing drinking water, facilitating irrigation, and offering a habitat for aquatic life (Aazami et al., 2015).

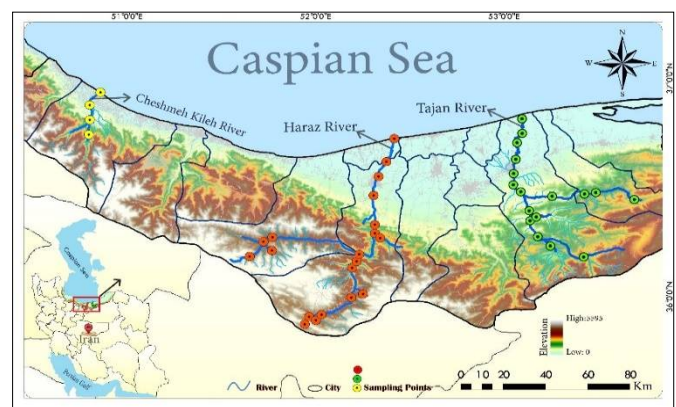


Figure 1. Map of the location of the Tajan, Haraz, and Cheshmeh Kileh rivers

2.3 Haraz River

The Haraz River (Table 1), which is the second largest river in the Caspian Sea basin following the Sefidrud (Roshani-Sefidkouhi et al., 2025), has its origins in the southern slopes of the Alborz Mountains. Its source is located near Mount Damavand, the highest peak in Iran, standing at 5,671 meters. The basin encompasses an area of approximately 4,972.09 km², with the main channel extending about 155.23 km and exhibiting an average slope of 1.62%. The river predominantly flows from south to north. Significant tributaries of the Haraz include Lar, Shir Kalarud, and Nur River, among others. The river traverses various urban and agricultural regions, encountering pollution issues due to wastewater discharge and agricultural runoff.

2.4 Cheshmeh Kileh River

The Cheshmeh Kileh River (Table 1) is situated in Tonekabon County, which is part of the western Mazandaran Province (Roshani-Sefidkouhi et al., 2025). It has its source in the highlands close to Mount Takht-e Soleiman, where elevations can reach as high as 4,637 meters. The river basin spans an area of approximately 776.2 km², featuring a main channel that extends 51.6 km in length and exhibits a relatively steep average gradient of 4.6%. The formation of the Cheshmeh Kileh River occurs through the merging of two

major tributaries, Dohezar and Sehezar, along with a smaller tributary known as Valamrud. This river plays a crucial role in supporting local agricultural activities and offers significant aquatic habitats (Aazami et al., 2015).

Table 1. Morphometric Characteristics of Tajan, Haraz, and Cheshmeh Kileh-River Basin

Parameter	River Basin		
	Tajan	Haraz	Cheshmeh Kileh
Basin Area (km ²)	4,147.22	4,972.09	776.2
Maximum Elevation (m)	3728	5671	4637
Minimum Elevation (m)	-26	-26	-23
Main Channel Length (km)	151.57	155.23	51.6
Average Slope (%)	0.85	1.62	4.6
Major Tributaries	Chahardangeh, Khorramabad, Rudbar, Sefidrud	Lar, Shir Kalarud, Nur River	Dohezar, Sehezar, Valamrud

2.5 Study Design and Sampling Stations

In this study, to effectively evaluate water quality, the following sequential steps were executed: (1) Gathering physicochemical data from water quality monitoring stations located in three northern rivers (Haraz, Tajan, and Cheshmeh Kileh) for the years 2021 and 2023. (2) Analyzing the data and ensuring the quality of the information, which included the elimination of any missing or erroneous data. (3) Computing a quality score (Q-value) for each parameter based on the reference tables corresponding to each index.

(4) Assigning weights to each parameter in accordance with the NSFQI, IRWQI, and BCWQI index frameworks. (5) Merging Q-values and weights to derive the final value of each index for every station. (6) Categorizing the results into five or six levels (according to WQI indices) as per the guidelines for each index. (7) Conducting spatial and temporal analyses of the indices and creating comparative charts for each river. A total of 40 sampling stations were chosen along the three rivers, distributed as follows: (1) Haraz River: 19 stations; (2) Tajan River: 17 stations; (3) Cheshmeh Kileh River: 4 stations.

In total, Sampling was carried out based on Iranian Standard No. 2347 of the Iranian Standards and Industrial Research Institute (ISIRI, 2005), the Environmental Protection Organization's water quality parameters sampling manual, and the water sampling method for microbial, physical, and chemical testing based on standards 9412 and 4208 of the National Standards Organization of Iran and ISO 5667-5, 2006. The number of samples collected in 2021 and 2023 amounted to 80. From each sample, 9 physicochemical and microbial parameters were assessed, including pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), turbidity, nitrate, phosphate, total solids (TS), and total coliforms. These stations were strategically positioned to represent upstream, midstream, and downstream sections, thereby capturing the effects of both natural and anthropogenic factors (Figure 1).

2.6 Physicochemical Parameters Measured

Water samples were analyzed for the following key physicochemical parameters in the Mazandaran regional water company laboratory (Table 2):

Table 2. Parameters and their measurement method and weight in the WQI index

Parameter	Abbreviation	Unit	Method of measurement	WQI	
				NSFWQI	IRWQI
Dissolved Oxygen	DO	mg/L	Using the SENSION6 portable DO meter	0.17	0.097
Biological Oxygen Demand	BOD	mg/L	5-day Incubation Method	0.11	0.17
pH	pH	-	Potentiometric method, pH meter electrode	0.11	0.051
Turbidity	-	NTU	Nephelometric method	0.8	0.62
Nitrate	NO ₃	mg/L	UV Spectrophotometry	0.1	0.108
Phosphate	PO ₄	mg/L	Ascorbic Acid method	0.1	0.087
Temperature	Temp	°C	Thermometer	0.1	-
Total Solids	TS	mg/L	Gravimetric method	0.7	-
Fecal Coliform	FC	MPN/100mL	Multiple Tube Fermentation (MPN) Method	0.16	0.140
Total Coliforms	TC	MPN/100mL	Multiple Tube Fermentation (MPN) Method	-	-
Electrical Conductivity	EC	µS/cm	Conductivity Meter	-	0.096
Total Dissolved Solids	TDS	mg/L	Gravimetric Method	-	-
Chemical Oxygen Demand	COD	mg/L	Nitration with sodium thiosulfate solution in the presence of alkaline iodide	-	0.093
Ammonium	-	mg/L	Spectrophotometry	-	0.090
Total Hardness	Th	mg/L of CaCO ₃	Titration with EDTA	-	0.059

2.7 Water Quality Indices Used

To assess the quality of surface water in Iranian rivers, various Water Quality Indices (WQIs) have been extensively utilized. Among these, the NSFQI, the IRWQI, and the BCWQI are the most frequently employed. Each index differs in its structure, choice of parameters, and weighting system, which affects its sensitivity to various pollution sources and determines its suitability for specific applications (Table 2). The subsequent table outlines the primary characteristics, advantages, and drawbacks of these indices, along with relevant scientific references that endorse their application in studies of water quality in Iran.

Each index includes particular parameters with established weights and scoring techniques to categorize water quality into qualitative classifications such as Excellent, Good, Moderate, Poor, and Very Poor (in NSFQI).

2.8 NSFQI Index

The NSFQI is one of the most widely applied composite water quality indices worldwide. It incorporates nine essential parameters: DO, BOD, pH, nitrate, phosphate, temperature, turbidity, TDS, and total coliform. The overall formula for this index is presented as follows:

$$\text{NSFQI} = \sum (w_i \times q_i) / \sum w_i \quad (\text{Formula 1})$$

w_i : Weight of each parameter

q_i : Its quality score (Q-value) or the weight (Table 2) of that parameter in the index (a number between 0 and 1, and the sum of the weights equals 1).

Following the computation of the quality score (Q-value) and its incorporation into the formula alongside the values of other parameters, the index value was determined. Subsequently, based on the quality classification table (Table 4), the final index value was computed and categorized as Excellent, Good, Moderate, Poor, and Very Poor (Horton, 1965).

2.9 IRWQI Index

One of the key indigenous indices developed for assessing Iranian surface waters is the physical and chemical index IRWQIsc, introduced by Roshani-Sefidkouhi et al. (2025). The index is computed using Formula 2.

$$r = \sum_{i=1}^n w_i \quad (\text{Formula 2})$$

l_i : The value of the physicochemical parameter

w_i : Parameter weight the index (Table 2) value for the i^{th} parameter of the target ranking curve of the mentioned index.

Water quality classifications based on IRWQI are given in Table 3: Very Bad, Bad, Relatively Bad, Medium, Relatively Good, Good, or Very Good.

2.10 BCWQI index

In this research, the BCWQI, along with its evolved version known as the CCME WQI, continues to be the subject of

various studies, highlighting its prominence. Developed in the late 1980s, it was designed to monitor local water quality. Its effectiveness prompted the Canadian Council of Ministers of the Environment to adopt this index in the late 1990s, with the CCME WQI being established as a single national standard for the entire country. Indeed, the CCME WQI, which is the advanced form of the BCWQI, was created to have a broader application.

This index was created by the Canadian Council of Ministers of the Environment and comprises three primary components to evaluate the severity and frequency of breaches of permitted limits. The final formula for the index:

$$\text{BCWQI} = 100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732 \quad (\text{Formula 3})$$

F1 (Scope): Percentage of parameters that have violated the permissible limits.

F2 (Frequency): Percentage of violations compared to the total number of samples.

F3 (Amplitude): The intensity of violations using the normalization formula.

Used parameters: COD, EC, BOD₅, DO, pH, Turbidity, TDS, PO₄, NO₃, FC

In this index, following the computation of the quality score (Q-value) and its incorporation into the formula alongside the values of other parameters, the index value is determined. Subsequently, based on the quality classification table, the final index value is computed and categorized as Excellent, Good, Fair, Marginal, or Poor (WATER, 2001).

2.11 Calculation of the Index

After the body of water, the period of time, and the variables and objectives have been defined, each of the three factors that make up the index must be calculated. The calculation of F1 and F2 is relatively straightforward; F3 requires some additional steps.

F1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

F2 (Frequency) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps.

A: The number of times by which an individual concentration is greater than (or less than, when the

objective is a minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{FailedTestValue_i}{Objective_j} \right) - 1$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_j}{FailedTestValue_i} \right) - 1$$

B: The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$nse = \frac{\sum_{i=1}^n excursion_i}{\# \text{ of tests}}$$

C: F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives

(nse) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

$$BCWQI = 100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732$$

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality.

2.12 Data Analysis and Quality Control

Data underwent quality control measures to remove missing or inconsistent records. Parameter values were standardized and converted into quality scores (Q-values) in accordance with the guidelines of each index. Subsequently, weighted scores were calculated to obtain the final WQI values for each station and year.

Table 3. Summary and References for Common Water Quality Indices (WQIs) Used in Iran

Index	Main Description / Notes
NSFWQI (National Sanitation Foundation Water Quality Index)	1- There is a high degree of relative validity in the rivers of Iran, particularly in areas where urban and agricultural wastewater significantly contribute to pollution. 2- The index employs specific weightings for parameters such as DO, BOD, coliform, and nitrate, which enhance its sensitivity to pollution. 3- It is effective in identifying point source pollution and the impacts of sewage. 4- The Iran Surface Water Quality Index is a native index specifically designed to suit Iran's hydrological and environmental contexts. 5- It incorporates EC and other parameters that are relevant to the local environment. 6- Some research indicates that the weights assigned to parameters in earlier versions require adjustment. 7- The index operates efficiently for local monitoring and in rivers affected by salinity.
IRWQI (Iran Water Quality Index)	1- An indigenous index (Iran Surface Water Quality Index) specifically designed for the hydrological and environmental circumstances of Iran. 2- Incorporates EC and other pertinent local parameters. 3- Certain studies indicate that the weights assigned to parameters in previous versions require adjustment. 4- Operates effectively for local monitoring and rivers impacted by salinity.
BCWQI (British Columbia Water Quality Index)	1- Created to evaluate adherence to particular standards (for instance, those related to drinking water or aquatic organisms). 2- Exhibits lower sensitivity to extreme pollution in comparison to NSFWQI. 3- Functions more effectively for evaluations tailored to specific uses (such as agricultural appropriateness).
1- Variations between indices are inherent because of differing parameter sets, weightings, and formulas. 2- IRWQI: Optimal for general management and local monitoring. 3- NSFWQI: The most dependable for identifying sewage and wastewater contamination. 4- BCWQI: Beneficial for evaluations tailored to specific purposes (e.g., agriculture). 5: The combined application (e.g., IRWQI + NSFWQI) provides a thorough assessment of water quality.	

Table 4. Water Quality Classifications Based on NSFWQI, IRWQI, and BCWQI

Index	Range	Classification
NSFWQI	90-100	Excellent
	70-89	Good
	50-69	Moderate
	25-49	Poor
	0-24	Very Poor
IRWQI	More than 85	Very Good
	70.1-80	Good
	55.1-70	Relatively Good
	45-55	Medium
	30-44.9	Relatively Bad
	15-29.9	Bad
BCWQI	Less than 15	Very Bad
	95-100	Excellent
	80-94	Good
	65-79	Fair
	45-64	Marginal
	0-44	Poor

3. Results and Discussion

3.1 Water Quality Index Scores and Classification

The assessed water quality indices (NSFWQI, IRWQI, and BCWQI) indicated both spatial and temporal variations across the three rivers (Table 5).

3.2 Haraz River

The NSFWQI and IRWQI typically suggested a moderate to good status of water quality at the majority of stations, whereas the BCWQI frequently categorized certain stations as Poor, highlighting its more stringent evaluation standards (Figure 2). Generally, the upstream stations exhibited superior quality in comparison to the downstream stations affected by urban and agricultural pollution.

Table 5. Average WQI Scores for 2021 and 2023

River	Year	NSFWQI			IRWQI			BCWQI		
		Index Scores	SD	Classification	Index Scores	SD	Classification	Index Scores	SD	Classification
Haraz	2021	61.2	5.4	Moderate	78.5	4.8	Good	25.3	20.2	Poor
	2023	59.5	7.0	Moderate	75.0	10.3	Good	20.1	20.1	Poor
Tajan	2021	55.0	5.7	Moderate	72.0	6.0	Good	18.7	10.2	Poor
	2023	53.2	6.8	Moderate	69.5	9.8	Relatively Good	15.4	7.6	Poor
Cheshmeh Kileh	2021	54.0	1.1	Moderate	70.5	2.0	Good	22.9	6.1	Poor
	2023	51.5	4.7	Moderate	67.0	6.5	Relatively Good	19.0	10.8	Poor

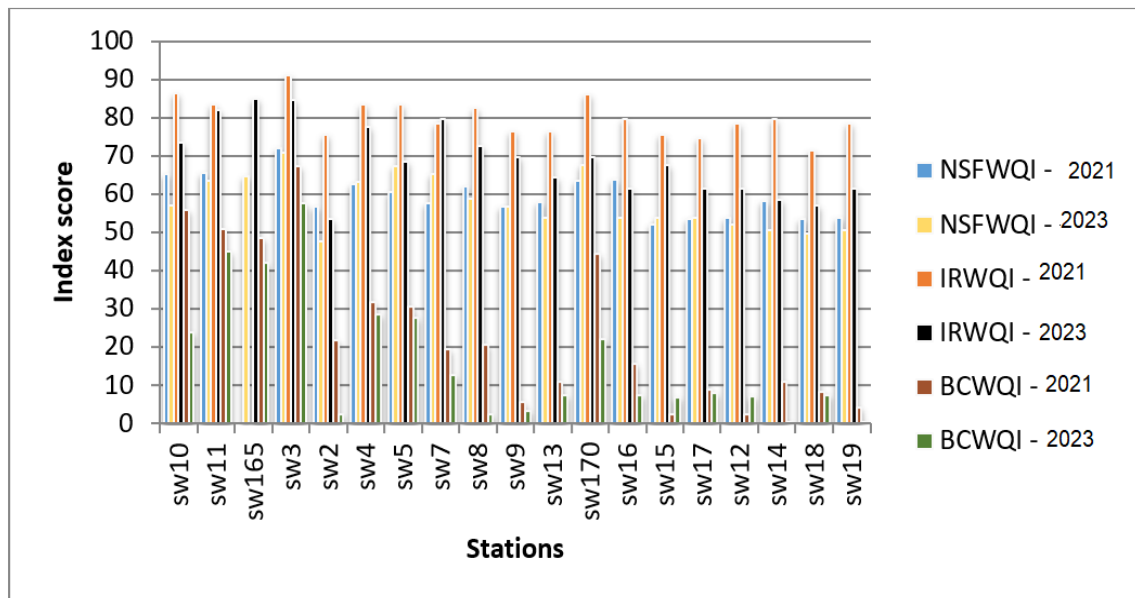


Figure 2. Comparison of water quality indicators in the Haraz River in 2021 compared to 2023

3.3 Tajan River

Comparable patterns were noted across the majority of stations classified as having Relatively Good and Moderate quality; however, the BCWQI distinguished itself by highlighting several stations with Poor conditions, primarily due to elevated concentrations of coliforms and nutrients (Figure 3).

3.4 Cheshmeh Kileh River

This river exhibited a generally lower quality of water, as indicated by the NSFQI and IRWQI, which reflect a moderate status. However, the BCWQI often assessed the river as Poor, particularly in the downstream sections (Figure 4). The results of this study clearly demonstrate the variability and complexity of river water quality in Mazandaran Province. The application of three distinct water quality indices (NSFWQI, IRWQI, and BCWQI) provided a multi-faceted view of the current conditions and trends.

Among the three indices, the BCWQI exhibited the greatest sensitivity to pollution, frequently categorizing stations as “Poor” particularly in downstream sections affected by urban and agricultural activities. This increased sensitivity

arises from the BCWQI’s strict thresholds and its focus on both the frequency and magnitude of water quality standard exceedances. Conversely, NSFQI and IRWQI often classified the water quality as “Moderate” to “Good,” reflecting their more generalized weighting schemes. While these indices provide useful overall assessments, they may underestimate localized pollution episodes that BCWQI effectively detects.

The quality of water typically deteriorated from the upstream to the downstream sections of all rivers, primarily due to escalating human-induced pressures, including wastewater discharge, agricultural runoff, and urban development (Roshani-Sefidkouhi et al., 2025).

The indices indicated a minor decline in water quality from 2021 to 2023, reflecting persistent pollution issues. Nevertheless, certain stations demonstrated stable or slightly enhanced conditions, likely as a result of localized management initiatives.

The results underscore the need for comprehensive water resource management strategies that employ multiple assessment tools to effectively monitor and address water quality challenges. The use of BCWQI in conjunction with NSFQI and IRWQI allows environmental authorities to

identify subtle yet significant changes, prioritize corrective measures, and enhance resource allocation. Furthermore, the research highlights the significance of reducing pollution from urban and agricultural sources, improving wastewater treatment facilities, and promoting community awareness to safeguard these essential river ecosystems.

For instance, Roshani-Sefidkouhi et al. (2025) reported a similar trend in Mazandaran’s Sefidroud River, where NSFQI values averaged 49 (“Poor”) while IRWQI values were higher at 56 (“Fairly Good”), showing that the indices differ in sensitivity. Likewise, Aghajanloo et al. (2022) observed that based on the results obtained from quality indicators, it can be concluded that the WAWQI index (Weighted Arithmetic Water Quality Index) is slightly more conservative in classifying water quality than the IRWQI index. These results are consistent with international

studies: (1) Yan et al. (2022) and Monira et al. (2024) that BCWQI provides a more conservative classification due to its inclusion of the frequency and magnitude of exceedances. (2) A meta-analysis by Ji et al. (2016), (Science of the Total Environment) also confirmed that multi-index assessments (such as NSFQI + BCWQI) yield a more holistic view of water quality trends than any single index alone.

Comparison of this study with domestic and international research shows that the findings are reliable, and the observed differences between the indices (especially the greater sensitivity of BCWQI) are fully consistent with global observations. These similarities indicate that the use of water quality indices in surface water studies can well reflect spatial and temporal changes in river water quality in humid regions with a temperate climate, such as Mazandaran Province.

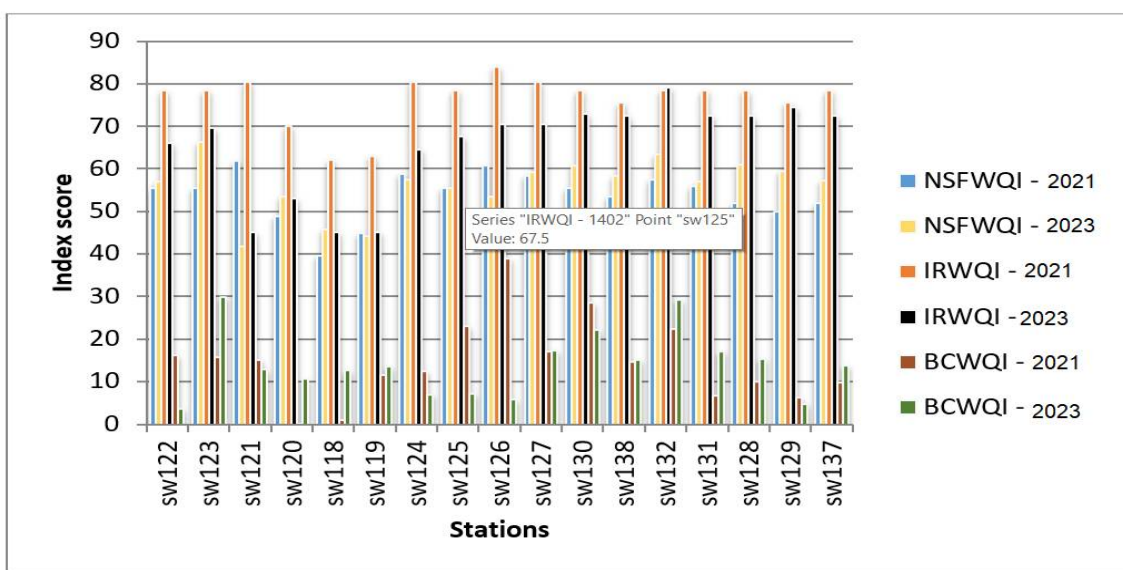


Figure 3. Comparison of water quality indicators in the Tajan River in 2021 compared to 2023

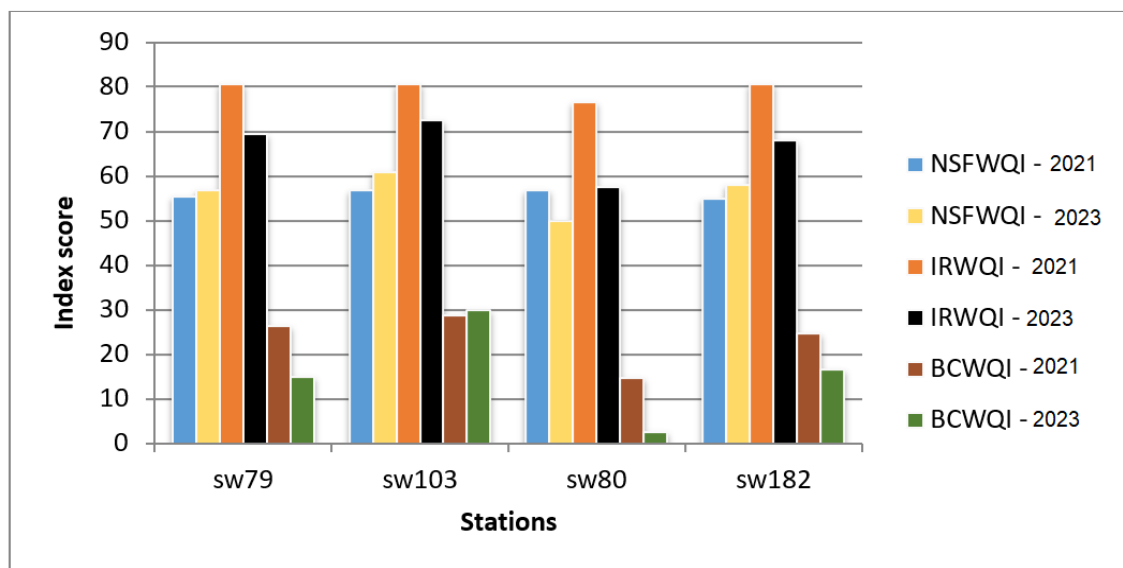


Figure 4. Comparison of water quality indicators in the Cheshmeh Kileh River in 2021 compared to 2023

4. Conclusion

This extensive research assessed the water quality of three significant rivers in Mazandaran Province, Iran, including Haraz, Tajan, and Cheshmeh Kileh, utilizing three recognized water quality indices (NSFWQI, IRWQI, and BCWQI). The results indicated Good to Moderate and Poor water quality conditions, with significant spatial and temporal variations primarily driven by human activities. However, BCWQI exhibited greater sensitivity to pollution and more effectively identified locations with serious water quality violations. The research also highlighted the decline in water quality from upstream to downstream areas and a slight reduction between 2021 and 2023. These findings lay a robust groundwork for integrated water management, stressing the necessity for enhanced pollution control, wastewater treatment, and environmental monitoring. Future studies should include biological indicators and seasonal evaluations to further enhance water quality assessments.

Our results demonstrated that the NSFWQI and IRWQI generally classified the water quality of the Haraz, Tajan, and Cheshmeh Kileh Rivers as Moderate to Good, whereas the BCWQI categorized several stations as Poor. This observation aligns with other national and international research highlighting that the BCWQI tends to be more stringent and sensitive to deviations from water quality standards.

Authors' Contributions

Mehrtaash Gholinezhad: Methodology; Formal analysis; Investigation; Resources; Writing (Original Draft). **Kaka Shahedi, Ghorban Vahabzade Kabria, Seyed Ramadan Mousavi:** Resources; Writing (Review and Editing). **Abbasali Zamani:** Methodology; Conceptualization; Supervision; Resources; Writing (Review and Editing).

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Ethical Considerations

This article does not contain any studies with human participants or animals performed by the authors. This study was approved by the Faculty of Natural Resources at Sari

Agricultural Sciences and Natural Resources University (Approval Code: 10174/03).

Using Artificial Intelligence

All authors confirm no artificial intelligence (AI) techniques were used in this research.

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