Gorgan University of Agricultural Sciences and Natural Resources

Environmental Resources Research (ERR)

Print ISSN: 2783-4832
Online ISSN: 2783-4670

Assessment of water quality of the Kashkan River using water quality indicators

Mohamed Sepahvand[1], Tahere Taghizade Firozjaee[2*], Jafar Abdi[3], Behnaz Latifian[1]

[1] MSc. student in Civil Engineering, Department of Water and Environmental Engineering, Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

[2] Assistant Professor, Department of Water and Environmental Engineering, Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

[3] Associate professor, Faculty of Chemical and Materials Engineering, Shahrood University of Technology, Shahrood, Iran

Article Info

Article type:
Research Article

Article history:
Received: December 2024
Accepted: March 2025

Corresponding author:
t.taghizade@shahroodut.ac.ir

Keywords:
Water quality assessment
Kashkan River
Water Quality Index
IRWQISC
NSFWQI
Wilcox

Abstract

River pollution is a critical issue with direct and indirect impacts on the health of humans, animals, and plants. In this study, ArcGIS software was used to delineate the Kashkan River path, and its water quality was assessed using the IRWQISC, NSFWQI, and Wilcox indices in comparison with global standards. Four sampling stations were established along the river, and water quality parameters were measured over one year, from autumn 2022 to summer 2023, using standard laboratory methods. The results revealed that water pollution increased from upstream to downstream, primarily due to agricultural drainage, industrial activities, and urban and rural sewage discharge. According to the IRWQISC index, stations S1 and S2 were classified as moderate quality, while stations S3 and S4 were categorized as relatively poor quality. Based on the NSFWQI index, all stations fell within the moderate quality category but did not meet the standards for drinking water. The Wilcox index indicated that the river water remains suitable for agricultural use. The study identified urban and rural sewage, along with agricultural runoff near the Kashkan River, as the main contributors to the decline in water quality. Cluster analysis grouped the sampling stations into two major categories based on their water quality characteristics. Therefore, it is recommended that environmental management strategies focus on continuous monitoring and identification of pollutants as a foundation for informed decision-making in this region.

Cite this article: Sepahvand, Mohamed; Taghizadeh Firozjaee, Tahere; Abdi, Jafar; Latifian, Behnaz. 2025. Assessment of water quality of the Kashkan River using water quality indicators. *Environmental Resources Research*, 13(1), 105-117.

DOI: 10.22069/ijerr.2025.23069.1462
Publisher: Gorgan University of Agricultural Sciences and Natural Resources

Introduction

Water is one of the most vital components of the environment, with rivers recognized as essential natural resources. In recent years, urbanization and increased pollution from the discharge of various wastewater types—including municipal, industrial, and agricultural effluents, as well as landfill leachate—have caused significant changes and declines in river water quality (Gholizadeh & Heydari, 2020). Given the vulnerability of river ecosystems, regular assessments are crucial for developing sustainable management strategies, especially considering the growing pollution sources driven by human activities and urban expansion. Therefore, prioritizing continuous evaluation and monitoring of river water quality is fundamental for the protection of global water resources (Khan et al., 2023; Saghafi et al., 2025).

Several water quality indices have been developed as effective tools to assess the condition of water bodies. These indices simplify complex, multi-parameter water quality data into a single numeric value, which is then categorized on a relative scale ranging from very poor to excellent. Such indices are widely used to monitor and control the quality of surface and groundwater and to support environmental management decisions. By reducing raw data complexity, water quality indices not only indicate current water quality but also reveal spatial and temporal trends (Ghamarnia et al., 2023).

Among these, the National Sanitation Foundation Water Quality Index (NSFWQI) is particularly significant. Using the NSFWQI classification allows for straightforward presentation and comparison of river water quality across different sampling stations, facilitating timely and accurate assessments. In Iran, the IRWQISC index—developed to reflect local conditions—has proven effective compared to other indices (Aminirad et al., 2021). Other commonly used indices include the Schuler diagram and World Health Organization standards for drinking water, the Wilcox diagram for agricultural suitability, and the Canadian Environmental Quality Guidelines for aquatic life.

Moreover, Geographic Information Systems (GIS) software has become instrumental in mapping pollution and providing detailed visualizations of surface water quality (Shamimuzzaman et al., 2019). By integrating spatial data, geographical layers, statistics, and field observations, GIS enables more precise prediction and analysis of water resource conditions. This supports decision-makers and environmental managers in implementing targeted actions to prevent pollution and improve water quality (Gholizadeh & Heydari, 2020).

Numerous studies have assessed surface and groundwater quality. For example, Alizadeh et al. (2017) evaluated the water quality of the Karaj and Kan rivers through sampling at 20 stations from September 2012 to June 2013, employing NSFWQI, IRWQISC, and WQI indices. The NSFWQI classified water quality as poor to average, IRWQISC rated it from very poor to relatively good, and the WQI assessment indicated good quality. Their findings suggested that the water was suitable for drinking and agricultural use. Similarly, Mirzaei et al. (2005), through zoning of the Jajrud River, found that water quality deteriorated due to microbial contamination, suspended solids, and increased turbidity.

The Kashkan River, located in Lorestan Province, Iran, is a vital waterway that significantly supports the region's ecosystem and economy. However, it has been increasingly impacted by pollution from various anthropogenic activities, posing serious risks to the environment and local communities. This study aims to evaluate the current pollution status of the Kashkan River, explore its potential consequences, and discuss possible mitigation strategies.

Materials and Methods

The study area

Lorestan Province, with an area of 28,160 square kilometers, is in the southwest of Iran and includes the Karkheh and Karun River basins. The Kashkan watershed is one of the important sub-watersheds of the Karkheh watershed. In terms of geographical location, the watershed is situated within 47 degrees and 12 minutes to 48 degrees and 59 minutes eastern longitudes and 33 degrees and 8 minutes to 34 degrees and 2 minutes northern latitudes, in the central part of the Zagros Mountain range, 450 kilometers southwest of Tehran. This basin is entirely located in Lorestan Province, and the districts of Khorramabad, Aleshtar, Kuhdasht, and Poldokhtar, covering approximately 33 percent of the entire province, are mainly within this basin (Mehdinasab et al. 2015). The watershed of the Kashkan River, with its 8 sub-watersheds, covers an area of approximately 9,560 square kilometers with a river length of about 300 kilometers, being roughly 22 percent of the total Karkheh watershed. Figure 1 shows the location of the river considered in this study.

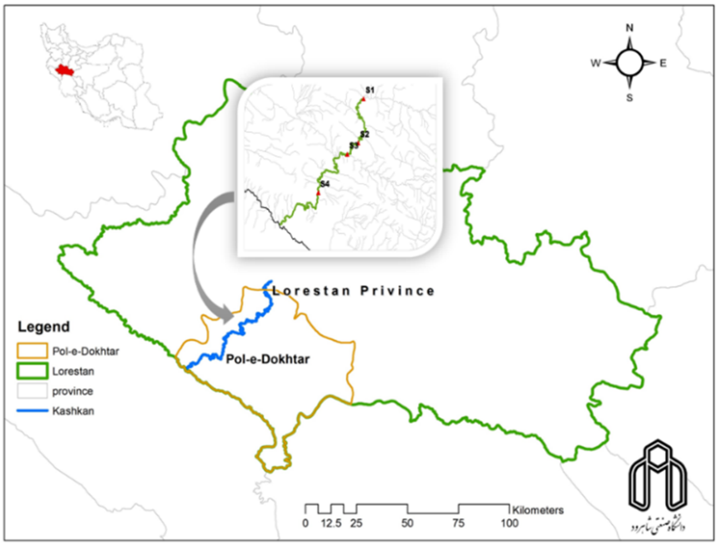

Figure 1. Location of the river under study.

The study area was selected as a focused segment within the broader plan for monitoring and assessing river water quality in Lorestan Province, aiming to identify zones with elevated pollution levels in alignment with Iran's national research and technological priorities in the water sector. Following field visits to over twelve potential sampling sites, four sampling stations were established. The selection criteria included insights from previous studies, the status of sub-basin outflows, proximity to villages and cities, expert consultation from the Lorestan Regional Water Company, as well as considerations of accessibility and spatial distribution to ensure comprehensive coverage of the study area.

Station 1 was positioned at the confluence of the two main tributaries of the Kashkan River. Stations 2 and 3 were located downstream near two populous and significant cities, while Station 4 marked the downstream endpoint of the study region. The precise geographical coordinates of these stations are detailed in Table S1, recorded using a GARMIN eTrex 30x GPS device.

Sampling was carried out quarterly across four seasons, from November 2022 to July 2023. Water samples were collected, preserved, and analyzed according to standard protocols. Subsequently, the collected data were evaluated using the IRWQISC, NSFWQI, and Wilcox water quality indices in accordance with both global and national standards. Additionally, spatial mapping of the river's water quality was performed utilizing Geographic Information System (GIS) techniques (Shamimuzzaman et al., 2019).

Water quality indicators

$IRWQI_{SC}$ water quality index

The $IRWQI_{SC}$ index is one of the IRWQI indices that evaluates water quality based on the presence of common quality parameters. In this index, a specific weight is assigned to each parameter (nitrates, phosphates, turbidity, dissolved oxygen, chemical oxygen demand, BOD_5, pH, total hardness, electrical conduction, fecal coliform, and ammonium), as shown in Table 1 (Nazari et al. 2020). To determine the index for each parameter, specific charts are available. Each parameter is ranked based on its qualitative value between 1 and 100 according to the corresponding curves (1 being the worst and 100 being the best quality). Then, the water quality index is determined from the geometric mean of the parameter rankings based on the weight assigned to each parameter. This index is designed in such a way that even if the number of measured parameters is less than 11, it is still reliable, but it is better to measure at least 6 parameters. To determine the water quality index, the following equations were used (Ghamarnia et al. 2023):

$$IRWQI_{SC} = \left[\prod_{i=1}^{n} I_i^{W_i}\right]^{\frac{1}{\gamma}} \quad (1)$$

$$\gamma = \sum_{i=1}^{n} W_i \quad (2)$$

where, W_i is the weight of the i-th parameter, n is the number of parameters, Ii is the index value for the i-th parameter from the ranking curve, and also using Table S2 (Dadkhah Tehrani et al. 2023), the water quality of the river was determined.

Table 1. Weight for each parameter in the $IRWQI_{SC}$ index.

Parameter	Unit	Weight factor
Fecal coliform	MPN/100mL	0.14
BOD_5	mg/L	0.117
NO_3^-	mg/L	0.108
DO	%sat	0.097
EC	mho/cmµ	0.096
COD	mg/L	0. 093
NH_4	mg/L	0.090
PO_4^{3-}	mg/L	0.087
Turbidity	NTU	0.062
Total hardness	mg/L	0.059
pH	-	0.051

NSFWQI qualitative index

The National Sanitation Foundation Water Quality Index (NSFWQI), introduced in 1970 with the support of the National Sanitation Foundation by Brown and colleagues, is one of the simplest and most widely used methods for assessing water quality (Brown et al. 1970). This index assesses water quality based on 9 water quality parameters, including dissolved oxygen, fecal coliform, BOD_5, pH, nitrate, phosphate, temperature variations, turbidity, and dissolved solids. Mathematically, NSFWQI can be expressed as the following equation (Khan et al. 2023):

$$NSF-WQI = \sum_{i=1}^{n} W_i\, C_i \quad (3)$$

Here, W_i represents the normalized sub-index of the i-th water quality variable, and C_i indicates the weight of the water quality variable as its importance. In this index, a specific weight (Table 2) is used for each parameter (Nazari et al. 2020), and the descriptive equivalent of the index, is calculated from Table S2 (Dadkhah Tehrani et al. 2023).

Table 2. Weight for each parameter in the NSFWQI index.

Parameter	Unit	Weight factor
Fecal coliform	MPN/100mL	0.16
BOD_5	mg/L	0.11
NO_3^-	mg/L	0.1
DO	%sat	0.17
T	C	0.1
PO_4^{3-}	mg/L	0.1
Turbidity	NTU	0.08
Total hardness	mg/L	0.07
pH	-	0.11

Wilcox index

The Wilcox diagram classifies water for agricultural uses into four classes based on electrical conductivity values (Wieczorek 2023). This diagram is based on two main factors, namely electrical conductivity and sodium adsorption ratio (SAR), which indicate the risk of alkalinity. The various groups mentioned in the Wilcox diagram, based on the values of these two parameters, inform farmers about the suitability of water for agricultural use. Based on the measurement of anion and cation concentrations in the soil saturation extract, these values represent the amounts of water-soluble ions (Salari, 2024). In this classification system, agricultural water is categorized into four groups—excellent, good, moderate, and unsuitable—based on electrical conductivity (EC) and the sodium adsorption ratio (SAR), as shown in Table 3. Additionally, a more detailed classification into 16 categories is presented in Table 4, where "S" denotes SAR and "C" denotes EC (Singhal & Gupta, 2010).

Table 3. Criteria for classifying water for agricultural use.

Category	SAR	Category	EC	Water quality
S1	SAR<10	C1	EC<250	Excellent
S2	10<SAR<18	C2	250<EC<750	good
S3	18<SAR<26	C3	750<EC<2250	Medium
S4	SAR>26	C4	EC>2250	Inappropriate

Table 4. Classification of water resource quality according to the Wilcox index.

Water classification	Water quality	Agriculture
C_1S_1	fresh water	Completely harmless
$C_1S_2.C_2S_2.C_2S_1$	little salty	Almost suitable
$C_1S_3.C_2S_3.C_3S_1.C_3S_2.C_3S_3$	salty	Use when necessary
$C_1S_4.C_2S_4.C_3S_4.C_4S_4.C_4S_3.C_4S_2.C_4S_1$	very salty	Harmful to agriculture

Results and Discussion

Water quality parameters of Kashkan River

After sampling from the study stations and conducting tests on the water samples, the values of the physicochemical and microbial parameters of the river were obtained, as shown in Table 5. During the study period, the water temperature of the Kashkan River ranged from 9.2° to 30.3°. The trend of seasonal changes in water temperature shows that the highest water temperature occurs in summer, while the lowest occurs in autumn. The difference in water temperature in different months can be due to variations in climatic conditions, humidity levels, duration of sunlight, and changes in topographical conditions (Effendi and Wardiatno 2015). Station number one, with an average annual temperature of 17.6°C, has the lowest temperature, while station number four, with an average annual temperature of 19.9°C, has the highest temperature. The results of the present study showed that the water temperature increases from the upstream to the downstream of the river. The influx of various types of urban, rural, domestic, and industrial wastewater plays a significant role in temperature changes. However, the increase in biological communities, biological activities, and the decomposition of organic materials, which lead to an increase in BOD and a decrease in DO, cannot be overlooked (Ghorbani et al. 2014). pH is very important in determining the health status of a river because water is used for direct human consumption, including drinking and bathing (Sharma and Kansal 2011). As seen in Table 5, the pH of the Khoshkan River water during the study period is alkaline, ranging from 7.25 to 8.21. Throughout the study period, Station 3 has the highest average pH (7.80), while Station 1 has the lowest average pH (7.58). The alkalinity of the river can be due to the geological conditions of the area, the composition of the riverbed, the high levels of dissolved salts in the water (resulting from erosion and dissolution of formations), the increasing trend of deforestation, the reduction of vegetation cover, and the presence of calcium and magnesium carbonate (Ghamarnia et al. 2023). The pH level of the Kashkan River water is suitable for drinking, agriculture, and industry at all stations, according to WHO standards and the Iranian Environmental Protection Organization. The lowest average DO levels are observed in the summer, while the highest DO levels are seen in the fall and winter, showing an inverse relationship with temperature, indicating that at higher temperatures, the dissolution of oxygen in water decreases (Kumar et al. 2011). The DO level of the Kashkan River water is suitable for drinking, agriculture, and industry at all stations, according to the standards of the WHO and the Iranian Environmental Protection Organization. According to Table 5, the highest BOD level (24 mg/L) and the lowest BOD level (1 mg/L) belong to summer and autumn, respectively. Additionally, the lowest average BOD (3.5 mg/L) is related to station number two, and the highest average BOD (9.5 mg/L) is related to station number three. The high BOD level at station number three could be due to the inflow of untreated waste and sewage from the cities of Mamulan and Afrineh. The BOD level of the Kashkan River water, based on WHO standards, is suitable for all stations and by the standards of the Iranian Environmental Protection Agency for drinking.

Additionally, the highest COD level (87 mg/L) and the lowest COD level (4 mg/L) belong to summer and winter, respectively. Also, the lowest average COD (16.5 mg/L) is related to station number two, and the highest average COD (35.5 mg/L) is related to station number three. The COD level of the Kashkan River water has been compared to the drinking water standards of the WHO and the Iranian Environmental Protection Agency. The water of the Kashkan River is classified as hard, with the highest total hardness at the stations occurring in the summer season, which is within the permissible range for drinking. The maximum average values of ammonium (0.46 mg/L), phosphate (2.93 mg/L), and nitrate (11.50 mg/L) are related to the winter season, which may be due to the entry of surface runoff from fields and runoff from rainfall into the river.

Electrical conductivity (Wieczorek 2023) is one of the qualitative parameters of water that indicates the ability of water to conduct electric current and is a function of the presence of dissolved ions in the water. Consequently, the level of electrical conductivity of a water sample has a direct relationship with the total dissolved solids (TDS) in the water, and generally, there is a linear relationship between EC and TDS in each water sample (Yaryan 2016). The lowest average EC and TDS levels were observed at station number one, while the highest average EC and TDS levels were observed at station number four. The average values of EC and TDS have shown an increasing trend from the upstream to the downstream of the river, which is due to factors including ion exchange, reverse ion exchange, evaporation, weathering, interaction between water and rock, sulfate oxidation and reduction processes, and anthropogenic sources such as the discharge of urban and agricultural wastewater along the river (Yaryan 2016). The acceptable levels of EC and TDS are defined based on WHO and Environmental Protection

Agency standards for drinking, agricultural, and industrial uses.

According to Table 5, the lowest fecal coliform value (34 MPN/100ml) was observed at station number two in winter, and the highest fecal coliform value (220 MPN/100ml) was observed at station number three in summer. As expected, with the influx of agricultural and, in some cases, rural wastewater, as well as recreational activities, the level of fecal coliform increases along the river's flow path (Aghaee et al. 2020). The fecal coliform level of the Kashkan River water, based on WHO standards, is unsuitable for drinking at all stations, and before using these sources for drinking and hygiene purposes, microbial treatment with common and conventional methods must be carried out. The winter season has the highest average turbidity level (139.7 NTU), which is due to the high amount of rainfall during this season and the increased entry of surface runoff and sedimentation in the river water. The turbidity level of the Kashkan River water is unsuitable for drinking at all stations, according to WHO standards and the Ministry of Energy standards.

Table 5. Measured parameters in different seasons at each station.

Parameter		T	pH	DO	BOD_5	COD	TUR	NO_3	PO_4	FC
Unit		^{0}C	-	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	MPN/100mg
Autumn	S1	9.20	7.29	8.64	4.00	13	48.80	9.50	1.20	38.00
	S2	9.90	7.41	10.15	1.00	4.00	54.50	9.90	1.30	34.00
	S3	9.50	7.56	9.15	2.00	7.00	132.00	10.00	1.25	37.00
	S4	10.30	7.40	9.02	2.00	10.00	149.00	10.40	1.20	92.00
Winter	S1	11.60	7.45	8.44	3.00	7.00	45.80	11.10	3.30	38.00
	S2	12.20	7.31	8.01	6.00	16.00	77.10	10.90	2.30	45.00
	S3	12.30	7.31	8.50	4.00	10.00	180.00	11.30	2.70	64.00
	S4	12.40	7.25	8.50	4.00	12.00	256.00	12.70	3.40	92.00
Spring	S1	22.70	7.69	8.35	3.00	15.00	51.00	8.50	0.20	70.00
	S2	25.10	8.03	8.30	3.00	19.00	88.60	8.20	0.60	84.00
	S3	25.40	8.18	7.74	8.00	38.00	144.00	8.40	0.60	130.00
	S4	26.50	7.91	8.57	2.00	21.00	145.50	8.60	0.40	94.00
Summer	S1	26.90	7.87	8.03	8.00	36.00	41.80	7.50	0.50	100.00
	S2	28.30	8.21	8.35	4.00	27.00	40.40	7.30	0.40	100.00
	S3	28.70	8.13	7.41	24.00	87.00	79.00	7.40	0.50	220.00
	S4	30.30	8.05	9.00	10.00	58.00	75.60	8.00	0.30	150.00

EC	TDS	NH_4	TH
µS/cm	mg/L	mg/L	mg-$CaCO_3$/L
457.00	286	0.04	200.00
655.00	410	0.03	159.00
948.00	593	0.04	229.00
951.00	595	0.08	202.00
330.00	207	0.38	157.00
325.00	204	0.35	167.00
590.00	369	0.49	243.00
566.00	354	0.61	208.00
385.00	241	0.04	165.00
530.00	332	0.01	221.00
853.00	534	0.03	271.00
979.00	612	0.04	191.00
410.00	257	0.05	191.00
570.00	357	0.02	226.00
520.00	325	0.05	214.00
1001.00	626	0.13	251.00

Water quality assessment using $IRWQI_{SC}$ and NSFWQI indices

The results of the water quality assessment at stations S1, S2, S3, and S4 of the Kashkan River from autumn 2022 to summer 2023, based on the $IRWQI_{SC}$ index (Table 6), showed that station S3 (summer 2023) had the lowest level (relatively poor quality) at 37.2, while station S1 (spring 2023) had the highest level (relatively good quality) at 60.1. Additionally, the lowest and highest average $IRWQI_{SC}$ index values were observed at station S3 with a value of 43.80 (relatively poor quality), and station S1 with a value of 54.43 (medium quality), respectively. Overall, the water quality at stations S1 and S2 was categorized as medium (45-55), while stations S3 and S4 were categorized as relatively poor (30-44.90). The winter season had the lowest (44.70, relatively poor quality) and the spring season had the highest (53.40, medium quality) average $IRWQI_{SC}$ index.

Based on the NSFWQI index (Table 6), station S3 (summer 2023) with a value of 55, had the lowest level with medium quality, and station S2 (autumn 2022) with a value of 69, had the highest level with medium quality. Additionally, the lowest and highest average NSFWQI values were observed at station S3 with a value of 58 (medium quality), and stations S1 and S2 with a value of 64 (medium quality), respectively. Overall, the water quality at stations S1, S2, S3, and S4 was classified as medium (50-69). The summer season had the lowest (59 medium quality) and the autumn season had the highest (64 medium quality) NSFWQI index.

Using the $IRWQI_{SC}$ and NSFWQI indices and utilizing ArcGIS 10.8.2 software, the water quality zoning of the Kashkan River is presented in Figs. 2a and 2b. In each of the zoning maps, the average index for each station over the sampling period from autumn 2022 to summer 2023 was calculated separately, and by obtaining a dimensionless number for each station, the water quality was determined according to the tables for each index. This number is categorized with a relative scale that indicates water quality from very poor to excellent. These indicators are simple and suitable tools for determining the status and conditions of water quality. This classification provides important information to researchers and managers and enables optimal water resource management and appropriate decision-making regarding the improvement of river water quality. According to Figure 2a, the average value of the $IRWQI_{SC}$ water quality index at stations S1 and S2 is equivalent to medium quality (45-55), and at stations S3 and S4, it is equivalent to relatively poor quality (30-44.9). This indicates that the water quality of the Kashkan River decreases from upstream to downstream. This also shows that moving downstream, water quality deteriorates significantly due to increased human activities, the influx of agricultural runoff and industrial and urban wastewater. According to Figure 2b, the average value of the NSFWQI water quality index at stations S1, S2, S3, and S4 is equivalent to medium water quality (69-50) and degree C, indicating that the water quality of the Kashkan River is consistent along the river's course.

Similar results have been reported in other studies. For example, Delbari et al. (2022) assessed the water quality of the Tajan River using the Iranian Surface Water Quality Index (IRWQISC). Their analysis of 11 water quality parameters across 9 sampling stations revealed that the IRWQISC index ranged from 7.23 to 8.70 in the cold season and from 21.64 to 35.16 in the warm season along the Tejen River. Overall, the river's water quality was classified as medium to poor, with pollution increasing near agricultural lands. Major pollution sources included sand and paper factories in Mazandaran, fish and livestock farming, sewage from Sari County and surrounding villages, and runoff from rice paddies and agricultural fields. These findings underscore the importance of comprehensive water resource management and environmental impact assessments in the region. Similarly, Sadeghi et al. (2016) evaluated the water quality of the Zaringal River in Golestan Province using the NSFWQI and IRWQISC indices. Their study, which analyzed 11 parameters across 9 stations, found that all stations fell into the medium category according to the NSFWQI index and into moderate or relatively good categories based on the IRWQISC index. While the water was suitable for agricultural use, treatment was necessary for drinking purposes.

In another study, Yusefzadeh et al. (2014) assessed the water quality of the Khoramroud River in Khorramabad using the NSFWQI index and Geographic Information System (GIS) technology. Key parameters—including pH, dissolved oxygen, total solids, biochemical oxygen demand, turbidity, temperature, phosphate, nitrate, and fecal coliform—were measured at six stations over six months in 2012. The results indicated that the first station had the highest water quality (NSFWQI = 82, "good") in August and November, while the sixth station showed the worst quality (NSFWQI = 42, "bad") in September and November. Water quality deteriorated progressively downstream, with stations classified as good (first station), medium (second to fourth stations), and poor (fifth and sixth stations). This study demonstrated the NSFWQI's utility in evaluating the impact of pollution sources on river water.

The results of cluster analysis for surface water quality assessment in the Kashkan River basin are presented in Figure 3. The dendrogram divides the sampling stations into two main clusters:

- Cluster 1: T3, Z4, Z3, Z2, T4, P3, P1, B3, and P4 (primarily downstream stations near Mamulan and Afrineh, influenced by point-source pollution and urban/rural runoff).

- Cluster 2: The remaining stations.

The clustering reflects correlations between qualitative water parameters, with homogeneous groups determined using the Ward method and Euclidean distance. Stations in Cluster 1 exhibited significant changes in water quality due to urban and rural influences, as well as seasonal surface runoff. The river's water quality is also affected by agricultural activities, road construction, and wastewater discharges. While dissolved oxygen and pH levels were relatively consistent across clusters, other parameters—particularly turbidity, fecal coliform, and BOD—showed marked differences. This demonstrates the effectiveness of cluster analysis in classifying homogeneous water quality groups.

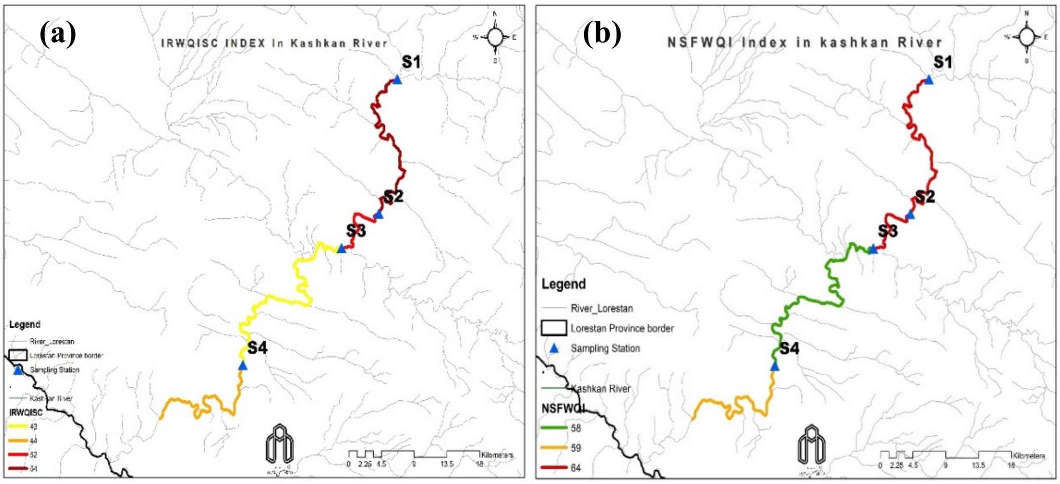

Figure 2. Mapping the water quality of the Kashkan River based on the average water quality index a) $IRWQI_{SC}$ b) NSFWQI.

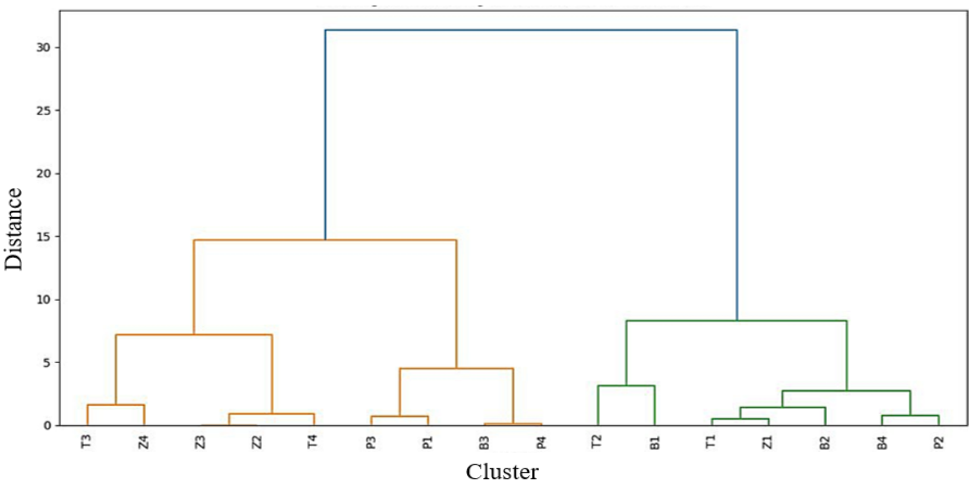

Figure 3. Dendrogram of hierarchical cluster analysis for the sampling station to evaluate the surface water quality of the Kashkan River basin (T= Summer, P= Autumn, Z= Winter, and B= Spring).

Water quality assessment using the Wilcox index

The Wilcox diagram is widely used to assess water quality for agricultural purposes. In this classification system, two key parameters—electrical conductivity (EC) and sodium adsorption ratio (SAR)—are considered critical. High salinity levels in irrigation water increase osmotic pressure in the soil solution, which can reduce water uptake by plants, while elevated sodium concentrations can negatively impact soil structure and plant growth. In this study, the Wilcox diagram for river water samples was generated using *Chemistry* software. As illustrated in Figure 4, approximately 70% of the water samples fall within the C2S1 category (*slightly saline—suitable for agriculture*), while 30% fall within the C3S1 category (*moderately saline—usable with caution*).

The seasonal classification of water quality based on the Wilcox index is presented in Table S3. According to the results, water samples from autumn fall into the C3S1 category, while those from winter, spring, and summer are categorized as C2S1. This seasonal variation is attributed to fluctuations in rainfall, which affect salinity concentrations in the river water. Overall, the results indicate that the water samples are predominantly in the *good to moderate* quality range for agricultural use and are considered suitable for irrigation.

Table 6. Evaluation of river water quality using the NSFWQI and $IRWQI_{SC}$ indexes.

Season	Station	$IRWQI_{SC}$		NSFWQI	
		Index rate	Descriptive equivalent	Index rate	Descriptive equivalent
Autumn 2022	S1	49.71	Medium	66	Medium
	S2	53.00	Medium	69	Medium
	S3	49.00	Medium	62	Medium
	S4	46.20	Medium	60	Medium
Winter 2022	S1	54.20	Medium	63	Medium
	S2	42.90	Relatively bad	60	Medium
	S3	42.90	Relatively bad	60	Medium
	S4	38.80	Relatively bad	57	Medium
Spring 2023	S1	60.10	Relatively good	68	Medium
	S2	55.20	Relatively good	63	Medium
	S3	46.10	Medium	55	Medium
	S4	52.20	Medium	61	Medium
Summer 2023	S1	53.70	Medium	61	Medium
	S2	57.00	Relatively good	64	Medium
	S3	37.20	Relatively bad	55	Medium
	S4	42.10	Relatively bad	56	Medium

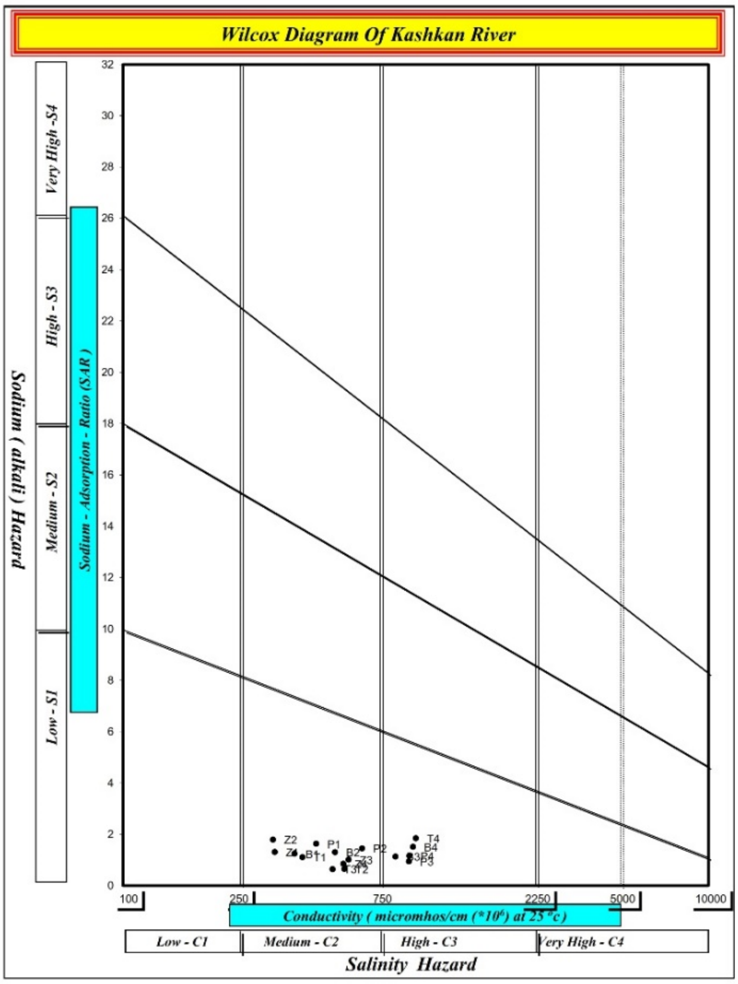

Figure 4. Wilcox diagram of the river water under study.

Conclusion

Rivers are significantly impacted by urban and rural expansion, industrialization, and other human activities, with numerous pollutants being discharged into the water. This leads to serious environmental and health concerns. Therefore, conserving water resources is vital for both environmental sustainability and human well-being. In this study, a field investigation was conducted to assess the water quality of the Kashkan River in Lorestan Province. Four sampling stations were selected, and water quality assessments were carried out over four seasons, from autumn 2022 to summer 2023. Water quality parameters were analyzed using the IRWQISC and NSFWQI indices, while the Wilcox index was applied to evaluate the suitability of the water for agricultural use.

The average IRWQISC values indicated that stations S1 and S2 had medium water quality, whereas stations S3 and S4 showed relatively poor quality. This reflects a decline in water quality from upstream to downstream, primarily due to increased human activities, agricultural runoff, and the discharge of industrial and urban wastewater. In contrast, the average NSFWQI values at all four stations indicated moderate water quality, suggesting a relatively consistent quality level along the river's course. Based on both the IRWQISC and NSFWQI indices, the water does not meet the required standards for drinking and must undergo physical and microbial treatment before use. However, the Wilcox index results show that the river water is suitable for agricultural purposes. These findings provide valuable insights for environmental policymakers in addressing pollution and preserving the health of the Kashkan River ecosystem.

Declaration of Competing Interest

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

Acknowledgments

The authors acknowledge the support provided by Shahrood University of Technology.

References

Aminirad, H., Abessi, O., Golbabaei Kootenaei, F., Mirrezaei, M. A., Taghizade Firozjaee, T., Saeidi, P., and Darvishi, G. 2021. Investigation of self-purification capacity and water quality of Haraz river during dry and wet season. Journal of Applied Research in Water and Wastewater. 8(1), 21-27.

Aghaee, M., Heshmatpoor, A., Mahmoodlu, M. G., and Morteza Seyedian, S. 2020. Investigation of Water Quality of Chehelchay River Using IRWQIsc Index. Environmental Science and Technology. 22(5), 153-166.

Alizadeh, M., Mirzaei, R., and Kia, S. H. 2017. Determining the spatial trend of water quality indices across Kan and Karaj river basins. Journal of Environmental Health Enginering. 4(3), 256-243.

Brown, R. M., McClelland, N. I., Deininger, R. A., and Tozer, R. G. 1970. A water quality index-do we dare. Water and sewage works. 117(10).

Dadkhah Tehrani, M., Karimi Darmian, S., moridi, A., and Khalili, R. 2023. Evaluation of water quality of Chalus River based on IRWQIsc and NSFWQI water quality index. Journal of Environmental Sciences Studies. 8(3), 7064-7072.

Delbari, F., Rezaei Tavabe, K., Mirvaghefi, A., Lahijanzadeh, A., Bagherzadeh Karimi, M., and Salamroodi, E. 2022. Evaluation of water quality of Tajan River using IRWQIsc index. Aquaculture Sciences. 10(2), 83-98.

Effendi, H., and Wardiatno, Y. 2015. Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. Procedia Environmental Sciences. 24, 228-237.

Ghamarnia, H., Palash, Z., and Palash, M. 2023. Evaluation of Golin river quality in Kermanshah province using the standard surface water resources quality index of Iran ($IRWQI_{SC}$). Journal of Applied Research in Water and Wastewater. 10(1), 7-14.

Gholizadeh, M., and Heydari, O. 2020. Evaluation of Gorganrood River water quality based on surface water quality indicators in Gonbad Kavous. Iranian Journal of Health and Environment. 13(1), 33-48.

Ghorbani, A., Mohammadi, M., and Mohammadi, Z. 2014. Water quality evaluation of Torghabeh River of Mashhad using combination of NSFWQI index and geographic information system. International Journal of Advanced Biological and Biomedical Research. 2(8), 2416-2430.

Khan, M. H. R. B., Ahsan, A., Imteaz, M., Shafiquzzaman, M., and Al-Ansari, N. 2023. Evaluation of the surface water quality using global water quality index (WQI) models: perspective of river water pollution. Scientific Reports. 13(1), 20454.

Kumar, R. N., Rajal Solanki, R. S., and Kumar, J. 2011. An assessment of seasonal variation and water quality index of Sabarmati River and Kharicut canal at Ahmedabad, Gujarat. 2248-2262.

Mehdinasab, M., Tavousi, T., Negaresh, H. 2015. Modeling of Rainfall - Runoff Kashkan River Catchment Based on Statistical Models. Geography and Environmental Planning. 26(2), 67-84

Mirzaei, M., Nazari, A., and Yari, A. 2005. Qualitative zoning of Jajroud River. Environment. 31(37), 17-26.

Nazari, E., Egdernezhad, A., and Jalilzadeh, Y. R. 2020. Monitoring of Khuzistan water resources quality for use in domestic, industrial, and agricultural purposes using IRWQIsc and NSFWQI indices. Journal of Research in Environmental Health. 6(2), 117-133.

Saghafi, S., Taghizade Firozjaee, T., and Golbabaei Kootenaei, F. 2025. Assessment of Drinking Water Quality in Mazandaran Province, Iran. Iranica Journal of Energy and Environment. 16(2), 364-371.

Salari, M. 2024. Investigating groundwater quality using water quality indicators for drinking, agriculture and industry (Case study: Shiraz plain). Journal of Environmental Sciences Studies. 8(4), 7574-7586.

Shamimuzzaman, M., Nayeem, R. H., Ara, N., Rahman, M. M., Jahid, M. I. K., and Hasan, M. N. 2019. Physico-chemical and microbiological quality assessment of supply water around Dhaka city, Bangladesh. Journal of Water Resource and Protection. 11(03), 280.

Sadeghi, M., Bay, A., Bay, N., Soflaie, N., Mehdinejad, M. H., and Mallah, M. 2016. The survey of Zarin-Gol River water quality in Golestan Province using NSF-WQI and $IRWQI_{SC}$. Journal of Behdasht dar Arseh (i.e., Health in the Field). 3(3), 27-33.

Sharma, D., and Kansal, A. 2011. Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). Applied water science . 1, 147-157.

Singhal, B. B. S., and Gupta, R. P. 2010. Applied hydrogeology of fractured rocks, Springer Science & Business Media.

Wieczorek, B. 2023. Air Pollution Patterns Mapping of SO_2, NO_2, and CO Derived from TROPOMI over Central-East Europe. Remote Sensing. 15(6), 1565.

Yaryan, M. A. 2016. Using WQI to assess metal and microbial contamination of Gorganrud River. MSc Thesis in Environmental Geology, Shahrood University of Technology.

Yusefzadeh, A., Khorramabadi Shams, G., Godini, H., Hoseinzadeh, E., and safari, M. 2014. The assessment of khorramabad River water quality with National Sanitation Foundation Water Quality Index and Zoning by GIS. Quarterly Research Journal. 15(5), 82-92.