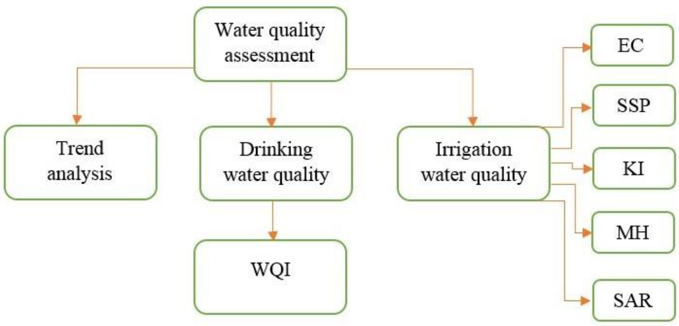
Journal of Applied Research in Water and Wastewater
E-ISSN: 2476-6283
Journal homepage: https://arww.razi.ac.ir

Assessing the suitability of river water quality using water quality indices: A case study on Balikhlou river in northwest of Iran

Saeed Rasi Nezami[1,*], Reza Aghlmand[2]

[1]Department of Civil Engineering, Faculty of Engineering, University of Mohaghegh Ardabili, Ardabil, Iran.
[2]Department of Civil Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article type:
Research Article

Article history:
Received 1 January 2023
Received in revised form 5 April 2023
Accepted 7 April 2023
Available online 9 April 2023

Keywords:
Trend analysis
Water quality assessment
Water suitability
Balikhlou river

ABSTRACT

Rivers are valuable sources of water supply for various purposes. These sources are seriously exposed to quality degradation due to the entry of various contaminants. Therefore, proper monitoring and quality management of these resources could be very important. In the present study, the quality of the Balikhlou river in Ardabil province, northwest of Iran, was investigated by surveying the trend of changes in river quality parameters, as well as water quality indices. In this study, after collecting the available data, by determining the trend of changes in quality parameters, the suitability of the studied river water quality for drinking and irrigation purposes was determined. The results indicated that there is an inverse relationship between changes in river discharge rate and the concentration of qualitative parameters. Therefore, it was found that salinity-containing pollution sources enter the river upstream of the desired station. Besides, the results of water quality indices showed that the water quality of the studied river is very poor for drinking (WQI>75). In addition, the results of water quality assessment for irrigation use based on SAR, KI, and SSP indices were generally considered inappropriate (SAR>26, KI>1, SSP>50), EC was often permissible (750<EC<2250), and MH was appropriate (MH<50). Our study highlights the importance of river water quality studies over time and thus can lead to better management of these valuable resources.

1. Introduction

Proper quality of water resources leads to ecological and economic development. However, as a result of many stresses on water quality, including human activities, increasing consumption of water resources, and natural processes (e.g., weathering, soil erosion, etc.), the deterioration of water quality around the world has become a serious problem (Wu et al. 2018). Rivers are the main sources of water for drinking, industrial, and agricultural uses, and the vital role of rivers in transmitting pollution in these areas makes them easily polluted (Singh, Malik, and Sinha, 2005). Therefore, due to the special importance of rivers, it is necessary to control and manage their quality degradation. Many studies have been conducted around the world to study the quality of river water (Nikoo et al., 2011; Mustapha et al., 2013; Kumarasamy et al., 2014; Effendi, 2016; Son et al., 2020; Xu et al., 2019).

One of the approaches for qualitative analysis of river water is time series analysis. Assessing long-term trends in water quality is a subject of growing interest (Abaurrea et al., 2011) and currently, various studies have been performed using time series and/or trend analysis of water quality parameters (Mattikalli, 1996; Karakaya and Evrendilek, 2010; Parmar and Bhardwaj 2014; Arya and Zhang 2015; Parmar and Bhardwaj, 2015; Tamagnone et al., 2019; Mahmoodi et al., 2021).

Another important approach in the assessment of rivers-water quality is using water quality indices (Bora and Goswami, 2017; Ewaid and Abed, 2017; Akinbile and Omoniyi, 2018; Judran and Kumar, 2020; Lkr, Singh, and Puro, 2020; Şener, Şener, and Davraz, 2017; Tian et al., 2019). Water quality indicators depict the overall quality of water by

*Corresponding author Email: rasinezami@uma.ac.ir

Cite this article: S. Rasi Nezami, R. Aghlmand, Assessing the suitability of river water quality using water quality indices: A Case study on Balikhlou river in northwest of Iran, *Journal of Applied Research in Water and Wastewater*, 10 (1), 2023, 1-6. https://doi.org/10.22126/arww.2022.7574.1239

converting various physical and chemical parameters into a single value (Avvannavar and Shrihari, 2008).

In the present study, to investigate the water quality of the Balikhlou river in Ardabil province, northwest of Iran, both mentioned approaches (i.e., time series analysis, and water quality indices) have been used. First, water quality data of the studied river were collected from Ardabil Regional Water Company. Then, the temporal changes in the parameters were surveyed during 1968 to 2011. This study identified the strong and inverse relationship between river discharge and concentration of qualitative parameters in the second half of the study period that indicate the entry of external pollution into the studied river. Then, the suitability of the studied river water for drinking and irrigation purposes was investigated; For this purpose, various water quality indices were used and the results were reported. In this study, to calculate the water quality index (WQI), a combination of the wide range of important parameters was used so that this index can reflect the status of river water quality more realistically. Besides, WQI was calculated for six two-month periods, and thus, the WQI changes over a year were also determined. On the other hand, indices determining the suitability of water quality for irrigation were also calculated for the entire period 1968-2011 to determine changes in each of them over time. The present study highlights the importance of river water quality studies over time, as it can show the effectiveness of river water quality planning and management. The results of this study can provide a better picture of Balikhlou River water quality status and will be useful for further planning as well as water quality studies in the future.

2. Materials and methods

2.1. Study area

Balikhlou river basin is located in Ardabil province between latitude and longitude of 37°46´N to 38°22´N and 47°46´E to 48°42´E, respectively (Fig. 1) (Aalipour erdi et al., 2018). Balikhloo river, which originates from the southeastern areas of Sabalan mountain, is one of the most important rivers in Ardabil. This river enters Ardabil city from the southwest and after passing through the city, this river enters the Qareh-Su river and then enters the Caspian Sea through the Aras river. The length of the Balikhlou river is 78 km and the area of the study basin is about 1600 km^2, which mainly includes high mountainous areas. The average precipitation in the study area is 329.6 mm/year, of which 40.2% occur in spring, 7.5% in summer, 24.9% in autumn, and 27.4% in winter. The cities of Nir, Ardabil, and Sarein are located as the three main urban areas within the watershed of the Blikhlou river.

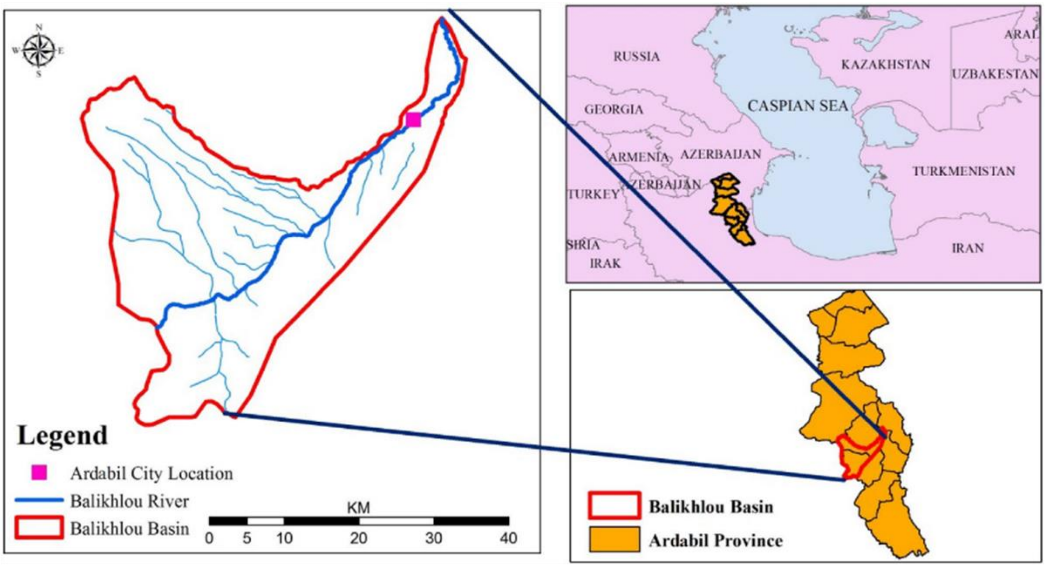


Fig. 1. The location of the study area.

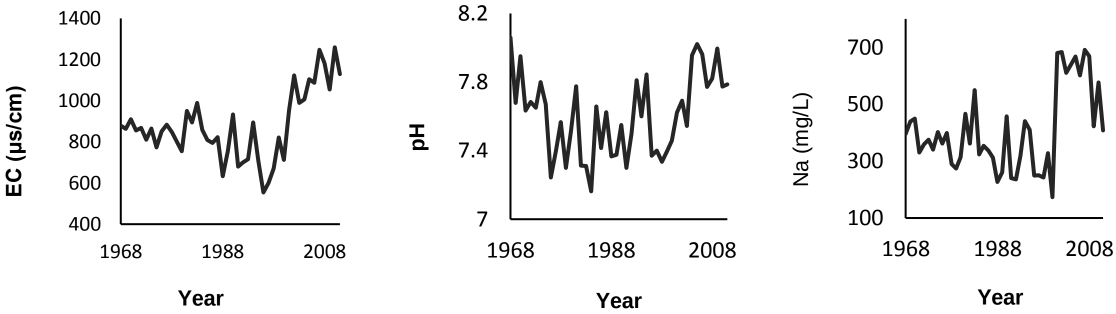
2.2. Data collection

In the present study, to assess the water quality status of the study case, statistics and information of quality parameters were collected and reviewed; These data include parameters of TA (total alkalinity), TDS (total dissolved solids), pH, TH (total hardness), TSS (total suspended solids), BOD (biochemical oxygen demand), COD (chemical oxygen demand), DO (dissolved oxygen), calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, electrical conductivity (EC), turbidity (NTU), bicarbonate, and phosphate. For the study area, only the long-term information (1968-2011) of the main cations (i.e., Na, Ca, and Mg) and anions (i.e., Cl, SO_4, HCO_3), pH, EC, and river discharge (Q) is available and recorded; The rest of the mentioned parameters have been measured and available only in the new study of Ardabil Regional Water Company in 2018.

3. Results and discussion

3.1. Time series analysis

Investigating the trend of changes in the river water quality parameters can show whether the quality management of water resources has been effective or not. Therefore, in this study, the changes of all qualitative parameters were surveyed, the results of which are as shown in Fig. 2. To calculate the temporal variation of the values of different parameters, the average value for each parameter in each year was used.



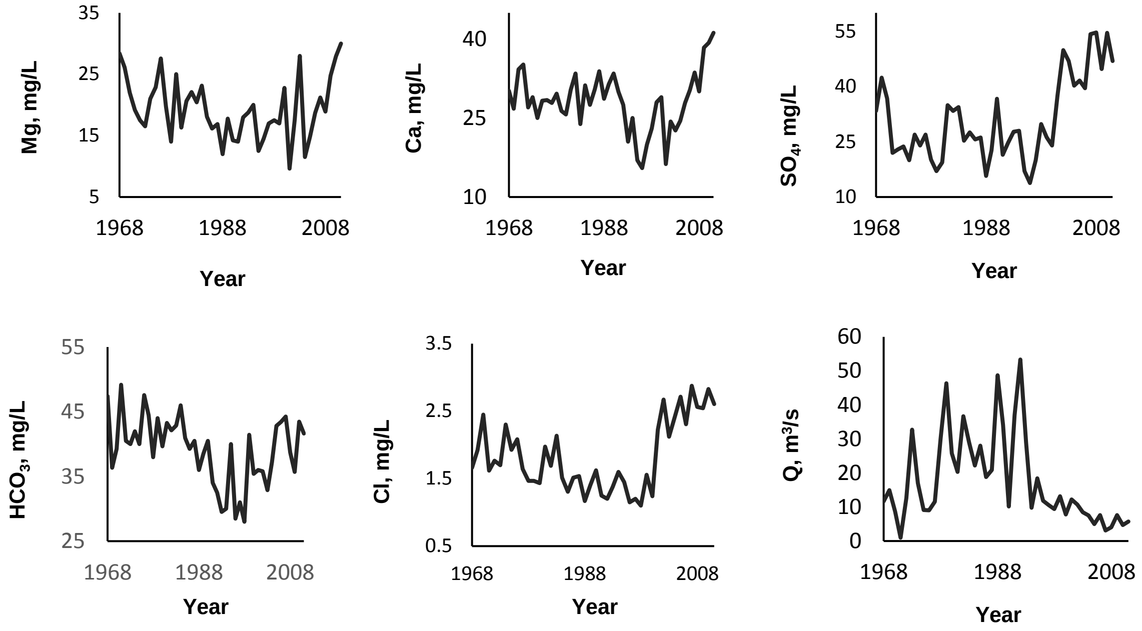


Fig. 2. Variations of water quality parameters of Balikhlou river during the period 1968 to 2011.

The time series diagram of changes in river discharge shows that since 1993, river discharge has decreased significantly so that the mean river discharge rate has decreased from about 53 m^3/s in 1992 to about 5.5 m^3/s in 2011. It is observed that with decreasing river discharge, the parameter Na concentration has increased. Generally, an inverse relationship between the discharge and Na towards the end of the study period may shows that the sources of pollution containing salinity enter the river upstream of the measuring station so that with decreasing the discharge of the river basin, the concentration of Na in the river increases. In fact, finding accurate sources of pollution requires an independent and extensive study.

Besides, the trend of HCO_3 concentration in the years after 1998 compared to the previous decades shows an increase. However, the increase of this parameter due to the natural buffering capacity of water, unlike other parameters, increases with a gentle slope. Also, the parameter of electrical conductivity (EC) in 1998 onwards due to the entry of salinity pollution sources into the river and on the other hand, a significant reduction in river discharge shows a significant increase.

The increase of chloride ion (Cl) in water from 1998 onwards indicates a significant inverse relationship with changes in river discharge and the entry of pollution sources often of agricultural origin along the river due to the use of sodium hypochlorite and calcium hypochlorite as disinfectants in agricultural products into the river in the upper parts of the studied station. The trend of changes in Ca, Mg, and SO_4 also follows the general trend of other quality parameters of the Balikhlou river.

3.2. Water quality index for drinking

In general, water quality indices are used primarily to assess river water suitability for drinking purposes. Water quality indices are techniques of rating that reflect the composite effect of different parameters. Indexing methods integrate numerous water quality variables into a single metric and are widely used in environmental science and engineering (Rajkumar, Naik, and Rishi, 2020).

The WQI calculation was performed to assess the suitability of the Balikhlou River for drinking purposes. The first step in calculating the WQI is to determine the weight assigned to each parameter. Weighting of chemical parameters is generally done according to their relative importance in the quality of drinking water (Ravikumar, Mehmood, and Somashekar, 2013). In the present study, the considered parameters (physical and chemical) in the WQI calculations are pH, TDS (total dissolved solids), TA (total alkalinity), TH (total hardness), TSS (total suspended solids), BOD (biochemical oxygen demand), COD (chemical oxygen demand), DO (dissolved oxygen), calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, electrical conductivity (EC), turbidity (NTU), and phosphate. Weighing from 1 to 5 is based on the relative importance of each parameter in drinking water quality, which is shown in Table 1.

Table 1. Relative weights assigned to each parameter.

Parameter	Unit	Water quality standard	Assigned weight (w_i)	Relative weight (W_i)
TA	mg/L	200	2	0.0308
TH	mg/L	500	4	0.0615
Potassium	mg/L	10	1	0.0154
Phosphate	mg/L	5	5	0.0769
Sodium	mg/L	200	3	0.0462
Nitrate	mg/L	50	5	0.0769
Sulfate	mg/L	250	2	0.0308
Chloride	mg/L	250	3	0.0462
Magnesium	mg/L	50	4	0.0615
Calcium	mg/L	75	4	0.0615
EC	µS/cm	1500	4	0.0615
pH	-	6.5-8.5	2	0.0308
TSS	mg/L	500	3	0.0462
TDS	mg/L	500	4	0.0615
BOD	mg/L	5	5	0.0769
COD	mg/L	10	4	0.0615
DO	mg/L	5	5	0.0769
Turbidity	NTU	5	5	0.0769
Total weights	-	-	$\sum w_i = 65$	$\sum W_i = 1.0000$

In calculating the WQI, it is necessary to use standard values of drinking water for different parameters. In this study, standard values for the studied quality parameters have been prepared from the drinking water quality standard of the World Health Organization and some recent studies (Ravikumar, Mehmood, and Somashekar, 2013; Das Kangabam et al., 2017; Bora and Goswami, 2017; WHO 2017; Hamlat and Guidoum, 2018; Karunanidhi et al., 2021). The water quality classification is based on the WQI value according to Table 2, which includes five general classes of unsuitable, very poor, poor, good and excellent quality for drinking (Brown et al., 1972).

Table 2. WQI classification.

WQI value	status	Possible usage
0-25	Excellent	All kind of uses
26-50	Good	All kind of uses
51-75	Poor	Irrigation and industrial uses (not drinking)
76-100	Very poor	Just for Irrigation use
Above 100	Unsuitable	Proper treatment required

WQI depicts the overall quality of water by converting several physical and chemical parameters into a single value (Avvannavar and Shrihari 2008; Mishra and Patel 2001; Vasanthavigar et al. 2010; Rakib et al. 2020) and is calculated using Eq. 1.

$$WQI = \sum_{i=1}^{n} SI_i \quad \text{while} \quad SI_i = W_i \times \frac{C_i}{S_i} \times 100 \qquad (1)$$

where, SI_i indicates the sub-index of the ith parameter, Wi shows the relative weight, C_i is the measured concentration of ith parameter, S_i is the standard value of ith parameter. After calculating the WQI, the results are as shown in Fig. 3. In general, the WQI results generally show that the water quality of the study river is very poor for drinking. It should be noted that the value of water quality index is higher in April to August.

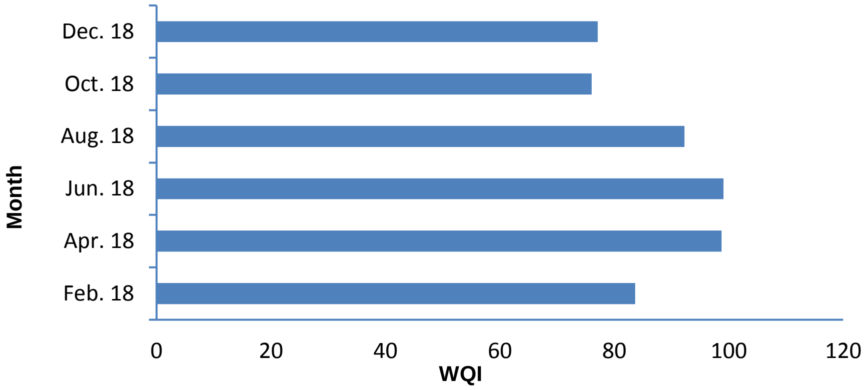


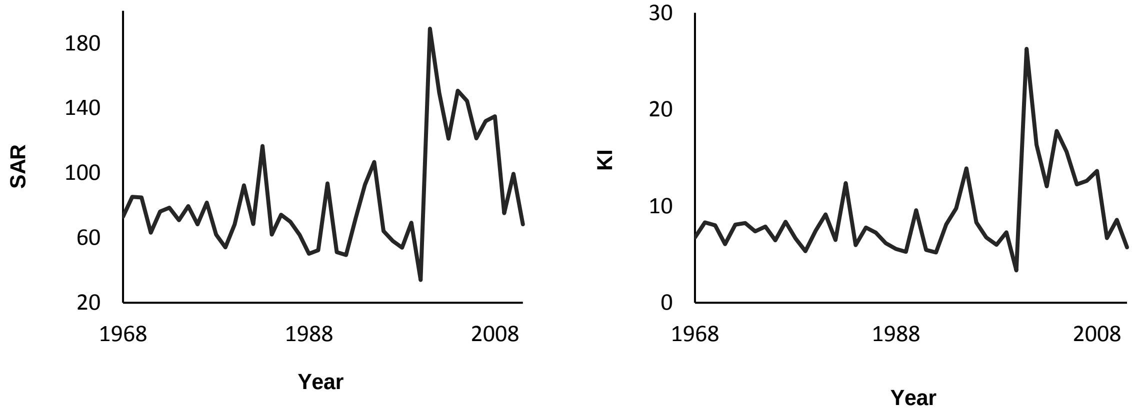
Fig. 3. WQI value in the study area during 2018.

3.3. Water quality indices for irrigation

Considering that the main source of agricultural water supply in the study area is the Balikhlou river, it is necessary to evaluate the quality of the study case in terms of suitability for irrigation purposes. In the present study, agricultural water quality assessment has been carried out using several water quality indices for irrigation include EC (electrical conductivity), SAR (sodium adsorption ratio), KI (Kelley's index), MH (magnesium hazard), and SSP (soluble sodium percentage), are listed in Table 3 (Ravikumar, Somashekar, and Angami, 2011). According to Table 3, to estimate the suitability of the river water for irrigation use, only the values of the main cations and anions are used to calculate the relevant indices. Therefore, in this study, considering the data of the main cations and anions for the whole period 1968-2011, qualitative indicators for all years of the period were calculated (Fig. 4). Also, the water quality classification for irrigation uses is according to Table 4 (Acharya, Sharma, and Khandegar, 2018).

Table 3. Water quality indices for irrigation (Ravikumar, Somashekar, and Angami, 2011).

Indices	Formula
Sodium adsorption ratio (SAR)	$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$
Kelley's index (KI)	$KI = \frac{Na^{+}}{Ca^{2+}+Mg^{2+}}$
Magnesium hazard (MH)	$MH = \left(\frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}}\right)\times 100$
Soluble sodium percentage (SSP)	$SSP = \left(\frac{Na^{+}}{Ca^{2+}+Mg^{2+}+Na^{+}}\right)\times 100$



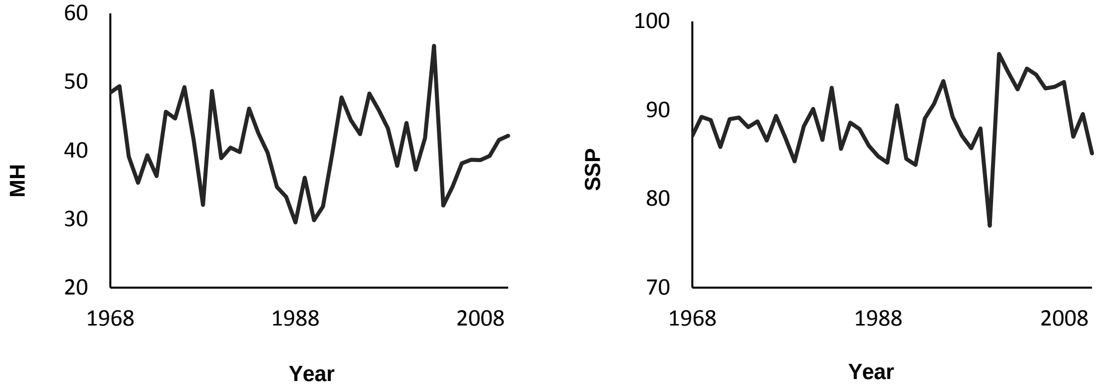


Fig. 4. Changes in the values of water quality indices for irrigation during the period 1968 to 2011 based on various indices.

Table 4. Classification of irrigation water quality (Acharya, Sharma, and Khandegar, 2018).

Indices	Range	Classification
EC	<250	Excellent
	250-750	Good
	750-2250	Permissible
	>2250	Doubtful
SAR	0-10	Excellent
	10-18	Good
	18-26	Doubtful
	>26	Unsuitable
MH	<50	Suitable
	>50	Unsuitable
KI	<1	Suitable
	>1	Unsuitable
SSP	<50	Good
	>50	Unsuitable

The results of the present study show that the amount of MH in the study period is generally below 50 and in this regard, the river water quality is suitable for irrigation purposes. Changes in EC over time (Fig. 2) indicate that according to the classification shown in Table 3, the water quality of the studied river is generally permissible for irrigation. However, the results of KI, SAR, and SSP indices show that for almost the entire period 1968-2011, the water quality of the Balikhlou river is unsuitable for irrigation purposes.

Now, some results of other studies are discussed. The results of the study by Ravikumar, Mehmood, and Somashekar (2013) showed that the WQI values in the Sankey tank belonged to the poor water class (WQI between 50.34 and 63.38). Also, the water of Mallathahalli lake was in the category of unsuitable water quality (WQI between 111.69 and 137.09). In another study, Ewaid and Abed (2017) concluded that the lowest WQI is for station 1 (WQI=43.0) which indicates good water quality. Stations 2, 3 and 4 also had WQI values of 67.2, 64.1 and 73.5, respectively, which were in the poor class in terms of water quality. Station 5 had a maximum WQI value of 88.7, which falls in very poor class. The overall WQI of their study river was 67.3, which indicates poor quality. The SAR value in the study of Ravikumar, Somashekar, and Angami (2011) in all samples was less than 10, which is in the excellent class for irrigation. The SSP ranged from 5.4 to 52.84 and generally was good (below 50). In addition, Kelly's index in their study ranged from 0.057 to 1.121, and all the water samples based on this index are suitable for irrigation, except for one sample (KI=1.121). Regarding the MH index, out of 47 samples, 23.4% of the samples were below 50 (suitable), while 76.6 % were in the category of unsuitable water quality (MH>50).

4. Conclusions

The present study provides valuable information about the general status of water quality in the Balikhlou river, Ardabil, using time series analysis of the river quality data and water quality indices. The water quality index (WQI) results showed that the quality of the studied river is almost unsuitable for drinking. The assessment of the suitability of river water quality for irrigation purposes using EC, SAR, MH, KI, and SSP indices revealed that the water quality of the Balikhlou river is also unsuitable for irrigation. Therefore, to improve the quality of the studied river water, it is necessary to take appropriate measures by the Ardabil Regional Water Company. It is suggested that in future studies, sources of river pollution be identified and solutions to improve the quality of the studied river be presented.

Author Contributions

Reza Aghlmand: Conceptualization, methodology, writing - original draft, writing - review & editing, data curation, investigation, formal analysis, validation.
Saeed Rasi Nezami: Supervision, writing - review & editing.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

The authors appreciate the Regional Water Company of Ardabil, Iran, for sharing the required information with them.

Data Availability Statement

Data will be available on request due to privacy and ethical restrictions.

References

Aalipourerdi M. *et al*. (2018) 'Surveying drinking water quality (Balikhlou River, Ardabil Province, Iran)', *Applied Water Science,* 8 (34), pp. 1-7. https://doi.org/10.1007/s13201-018-0653-6

Abaurrea *et al.* (2011) 'Trend analysis of water quality series based on regression models with correlated errors', *Journal of Hydrology*, 400 (3), pp. 341–352. https://doi.org/10.1016/j.jhydrol.2011.01.049

Acharya, S., Sharma, S.K., and Khandegar, V. (2018) 'Assessment of groundwater quality by water quality indices for irrigation and drinking in South West Delhi, India', *Data in Brief,* 18, pp. 2019–2028. https://doi.org/10.1016/j.dib.2018.04.120

Akinbile, C.O., and Omoniyi, O. (2018) 'Quality assessment and classification of Ogbese river using water quality index (WQI) tool', *Sustainable Water Resources Management,* 4, pp. 1023–1030. https://doi.org/10.1007/s40899-018-0226-8

Arya F.K., and Zhang L. (2015) 'Time series analysis of water quality parameters at Stillaguamish River using order series method', *Stochastic Environmental Research and Risk Assessment,* 29 (1), pp. 227–239. https://doi.org/10.1007/s00477-014-0907-2

Avvannavar, S.M., and Shrihari S. (2008) 'Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India', *Environmental Monitoring and Assessment,* 143, pp. 279–290. https://doi.org/10.1007/s10661-007-9977-7

Bora, M., and Goswami D.C. (2017) 'Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India', *Applied Water Science,* 7, pp. 3125–3135. https://doi.org/10.1007/s13201-016-0451-y

Brown R.M. *et al.* (1972) 'A Water Quality Index—Crashing the Psychological Barrier', Thomas, W.A. (ed.) *Indicators of Environmental Quality*. Pennsylvania: Springer, pp. 173–182.

Das Kangabam, R. *et al.* (2017) 'Development of a water quality index (WQI) for the Loktak Lake in India', *Applied Water Science,* 7, pp. 2907–2918. https://doi.org/10.1007/s13201-017-0579-4

Effendi, H. (2016) 'River water quality preliminary rapid assessment using pollution index', *Procedia Environmental Sciences*, 33, pp. 562–567. https://doi.org/10.1016/j.proenv.2016.03.108

Ewaid, S.H., and Abed S.A. (2017) 'Water quality index for Al-Gharraf River, southern Iraq', *Egyptian Journal of Aquatic Research* 43 (2), pp. 117–122. https://doi.org/10.1016/j.ejar.2017.03.001

Hamlat, A., and Guidoum A. (2018) 'Assessment of groundwater quality in a semiarid region of Northwestern Algeria using water quality index (WQI)', *Applied Water Science*, 8, pp. 1–13. https://doi.org/10.1007/s13201-018-0863-y

Judran, N.H., and Kumar, A. (2020) 'Evaluation of water quality of Al-Gharraf River using the water quality index (WQI)', *Modeling Earth Systems and Environment*, 6 (2), pp. 1581–1588. https://doi.org/10.1016/j.ejar.2017.03.001

Karakaya, N., and Evrendilek F. (2010) 'Water quality time series for Big Melen stream (Turkey): its decomposition analysis and comparison to upstream', *Environmental Monitoring and Assessment*, 165 (), pp. 125–136. https://doi.org/10.1007/s10661-009-0932-7

Karunanidhi, D. *et al.* (2021) 'Revealing drinking water quality issues and possible health risks based on water quality index (WQI) method in the Shanmuganadhi River basin of South India', *Environmental Geochemistry and Health*, 43, pp. 931-948. https://doi.org/10.1007/s10653-020-00613-3

Kumarasamy, P. *et al.* (2014) 'Multivariate water quality assessment from the Tamiraparani river basin, Southern India', *Environmental Earth Sciences*, 71, pp. 2441–2451. https://doi.org/10.1007/s12665-013-2644-0

Lkr, A., Singh, M.R., and Puro, N. (2020) 'Assessment of water quality status of Doyang River, Nagaland, India, using Water Quality Index', *Applied Water Science*, 46 (10), pp. 1–13. https://doi.org/10.1007/s13201-019-1133-3

Mahmoodi, N. *et al.* (2021) 'Trend in river water quality: tracking the overall impacts of climate change and human activities on water quality in the Dez River Basin', *Journal of Water and Health,* 19 (1), pp. 159-173. https://doi.org/10.2166/wh.2020.123

Mattikalli, N.M. *et al.* (1996) 'Time Series Analysis of Historical Surface Water Quality Data of the River Glen Catchment, U.K', *Journal of Environmental Management,* 46 (2), pp. 149–172. https://doi.org/10.1006/jema.1996.0013

Mishra, P.C., and Patel R.K. (2001) 'Study of the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa', *Indian Journal of Environment and Ecoplanning*, 5, pp. 293–298. Available at: https://www.researchgate.net/publication/276264908_Study_of_the_pollution_load_in_the_drinking_water_of_Rairangpur_a_small_tribal_dominated_town_of_North_Orissa (Accessed: 1 Aug 2022).

Mustapha A. (2013) 'River water quality assessment using environmentric techniques: Case study of Jakara River Basin', *Environmental Science and Pollution Research*, 20, pp. 5630–5644. https://doi.org/10.1007/s11356-013-1542-z

Nikoo, M.R. *et al.* (2011) 'A probabilistic water quality index for river water quality assessment: A case study', *Environmental Monitoring and Assessment*' 181, pp. 465–478. https://doi.org/10.1007/s10661-010-1842-4

Parmar, K.S., and Bhardwaj, R. (2014) 'Water quality management using statistical analysis and time-series prediction model', *Applied Water Science,* 4, pp. 425–434. https://doi.org/10.1007/s13201-014-0159-9

Parmar, K.S., and Bhardwaj, R. (2015) 'Statistical, time series, and fractal analysis of full stretch of river Yamuna (India) for water quality management', *Environmental Science and Pollution Research*, 22, pp. 397–414. https://doi.org/10.1007/s11356-014-3346-1

Rajkumar, H., Naik, P.K., and Rishi M.S. (2020) 'A new indexing approach for evaluating heavy metal contamination in groundwater', *Chemosphere*, 245, pp. 1–20. https://doi.org/10.1016/j.chemosphere.2019.125598

Rakib, M.A. *et al.* (2020) 'Groundwater salinization and associated co-contamination risk increase severe drinking water vulnerabilities in the southwestern coast of Bangladesh', *Chemosphere,* 246, pp. 1–19. https://doi.org/10.1016/j.chemosphere.2019.125646

Ravikumar, P., Mehmood, M.A., and Somashekar R.K. (2013) 'Water quality index to determine the surface water quality of Sankey tank and Mallathahalli lake, Bangalore urban district, Karnataka, India', *Applied Water Science,* 3, pp. 247–261. https://doi.org/10.1007/s13201-013-0077-2

Ravikumar, P., Somashekar, R.K., and Angami M. (2011) 'Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India', *Environmental Monitoring and Assessment,* 173, pp. 459–487. https://doi.org/10.1007/s10661-010-1399-2

Singh, K.P., Malik, A., and Sinha, S. (2005) 'Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques— A case study', *Analytica Chimica Acta*, 538 (1-2), pp. 355–374. https://doi.org/10.1016/j.aca.2005.02.006

Son, C.T. *et al.* (2020) 'Assessment of Cau River water quality assessment using a combination of water quality and pollution indices', *Journal of Water Supply: Research and Technology—AQUA*, 69 (2), pp. 160–172. https://doi.org/10.2166/aqua.2020.122

Şener, Ş., Şener, E., and Davraz, A. (2017) 'Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey)', *Science of the Total Environment*, 584–585, pp. 131–144. https://doi.org/10.1016/j.scitotenv.2017.01.102

Tamagnone, P. *et al.* (2019) 'Hydrology of the Sirba river: Updating and analysis of discharge time series', *Water,* 11 (1), pp. 1–15. https://doi.org/10.3390/w11010156

Tian, Y. *et al.* (2019) 'Using a water quality index to assess the water quality of the upper and middle streams of the Luanhe River, Northern China', *Science of the Total Environment,* 667, pp. 142–151. https://doi.org/10.1016/j.scitotenv.2019.02.356

Vasanthavigar M. *et al.* (2010) 'Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India', *Environmental Monitoring and Assessment,* 171, pp. 595–609. https://doi.org/10.1007/s10661-009-1302-1

WHO (2017) *Guidelines for drinking-water quality: fourth edition incorporating the first addendum*. Available at: https://www.who.int/publications/i/item/9789241549950 (Accessed: 15 Aug 2022).

Wu, Z. (2018) 'Assessing river water quality using water quality index in Lake Taihu Basin, China', *Science of the Total Environment,* 612, pp. 914–922. https://doi.org/10.1016/j.scitotenv.2017.08.293

Xu, G. (2019) 'Seasonal changes in water quality and its main influencing factors in the Dan River basin', *CATENA*, 173, pp. 131–140. https://doi.org/10.1016/j.catena.2018.10.014