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Evaluation of Pasikhan River, north of Iran using water quality index (NSFWQI)

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ABSTRACT
Water quality indices are among the current techniques for monitoring rivers. Among the general indices of water quality, applying the national sanitation foundation water quality index (NSFWQI) results in precise research outcomes in a short period. Moreover, it enables the classification of river water quality of different stations with a simple expression. The present study, through applying NSFWQI as a water quality index, aimed at determining the water quality of Pasikhan River, located in the north of Guilan Province, Iran. Six sampling stations were set up along the river mainstream, and water samples were collected from these stations during 4 seasons (from autumn 2015 to summer 2016). Nine parameters including water temperature, turbidity, fecal coliform, NO_3^-, TS, PO_4^{3-}, pH, DO, and BOD were measured through standard methods. Based on the results, the quality of the river's water was categorized in the medium and bad classes in all sampling stations for all seasons. Moreover, the results showed that during the sampling seasons, the minimum average of NSFWQI was 52.00 ± 3.94 in the 4th station, while the maximum was 59.50 ± 1.50 in the 3rd station. However, both of them were in the category of medium quality. In general, the water quality values of the stations varied from 46 to 70 in different seasons. According to the results, the Pasikhan River's water quality is ranked in the category of medium quality.

Keyword: NSFWQI, Pasikhan River, Water quality.

INTRODUCTION
Population growth has accelerated the expansion of rural communities in recent years. Moreover, ignoring environmental issues has resulted in the penetration of increasing urban, rural, and agricultural pollutants into water resources (Kamali & Tatina 2010). Rivers are the most important renewable and vital resources of freshwater for agricultural, domestic, and industrial uses. It is important to consider the huge impact of human activities on water quality and environmental regulations related to water pollution, as well as attention to the quality of water resources. Hence, the sustainable management of water resources is necessary to provide safe water with good quality for different purposes (Nohegar 2011). Among the general indices of water quality, the national sanitation foundation water quality index (NSFWQI) leads to accurate and fast data gathering and analyses and enables the classification of river water quality of different stations with a simple expression. This index works based on determining parameters such as the dissolved oxygen, fecal coliform, pH, BOD, temperature changes, total phosphate, nitrate, turbidity, and total solids (Hosseini *et al*. 2012; Madadinia *et al*. 2013). Madadinia *et al*. (2013) studied the water quality of Karoon River, southwest of Iran reporting that the monthly water quality index was in the middle class, decreasing from the first to the last stations. Aghyani *et al.* (2013) evaluated the water quality of the Pasikhan River based on NSFWQI concluding that it enjoyed good water quality in both dry and moist seasons, at all of its five stations. In another study, Mohammadi *et al*. (2008) simulated the nitrate and phosphate elements of the Pasikhan River through using the model CE-QUAI-W_2. Mirmoshtaqy *et al*. (2011) studied the water quality of Sefidrud River, north of Iran classifying its water quality using NSFWQI and overall water quality index (OWQI) during winter, spring, and summer in five sampling stations, concluding that

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the river was in bad and very low quality based on average NSFWQI and OWQI respectively. In another study, through applying the NSFWQI, based on pollution indices and NSFWQI, Shokouhi *et al*. (2012) and Effendi *et al*. (2015) once working on Aydughmush Dam Reservoir in Iran and Ciambulawung River in the Banten province of Indonesia, respectively concluded that the communities living along the river bank and the micro-hydropower plant beside the river did not negatively affect the water quality of the river. Thakor *et al*. (2011) applied the WQI to evaluate the water quality of the Pariyej Lake in India and impacts of the industrial, agricultural, and human activities on the water quality of the lake, reporting that the water quality was poor and unsafe for human consumptions. Pasikhan River is one of the main rivers in the central part of Guilan Province, north of Iran. Nowadays, several factors including the mismanagement of the river basin, the existence of an industrial park (Shaft City), the existence of the neighboring sand grading factories, cities and villages around the river that discharge a lot of effluents into the river, the development of irrigation networks such as drainage canals around the river and their runoffs, and using its water for agricultural purposes are the main causes of the pollution in this river. This pollution might exert a significant impact on the physical, chemical, and biological properties of the river. It has been reported by the local officials that the river water is affected unpleasantly by these discharges and activities, hence, conducting the current study on its water quality seems necessary. This study was conducted from autumn 2015 to summer 2016 and the parameters for NSFWQI calculation were measured along the river.

MATERIALS AND METHODS

Study area

Pasikhan River is one of the main rivers of the Caspian Sea basin, and the Anzali Wetland sub-basin. Its catchment area is about 823 km^2. This river originates from an altitude of 2,800 m (above mean sea level) and is formed by the main branches of the Siah Mazgi, Choobar (Imamzadeh Ebrahim), and Chenarrudkhan rivers that eventually enters Anzali Wetland. With an average slope of 1%, the length of its main channel and permanent branches are 72 and 136 km, respectively (Mohammadpour *et al.* 2012).

Methodology

To monitor the water quality of Pasikhan River, six sampling stations were set up along its mainstream, and water samples were collected from each station during four seasons (from autumn 2015 to summer 2016). The sampling stations were selected by taking into account that several possible factors including sources of urban and industrial pollutants entering the river and also the farmlands under cultivation around the river may affect the water quality of the river (Table 1 and Fig. 1). NSFWQI is a criterion for classification of surface water based on standard parameters. This index is a mathematical tool to convert large amounts of water indexing information to a number without units that indicate the water quality. This quality index requires a normalization phase, which means that for each parameter a scale between 1 and 100 is necessary in which the number. 100 represents the highest quality. Based on the significance of parameters, each parameter will have a weight. These parameters include dissolved oxygen, pH, temperature changes, BOD, fecal coliform, turbidity, total phosphate, nitrate, and total solids (TS) (APHA, 2005). Using a mercury thermometer and turbidimeter, the water temperature and turbidity were measured in the field. For other parameters, the samples were transported at 0 °C to a laboratory in the shortest possible time. Then the parameters were measured in the lab through some standard methods and analytical devices (Table 2) (APHA, 2005).

Table 1. Sampling stations in Pasikhan River.

Station number	Station name	Longitude	Latitude	Altitude
1	Badab bridge	356132E	4110373N	56.5
2	Shaft Industrial Zone	357820E	4110614N	42.9
3	Seyqhal koome	361065E	4111426N	23
4	Khatiban bridge	362367E	4113230N	14.5
5	Pasikhan dam	364642E	4124677N	-10.5
6	Nokhale	367217E	4136893N	-23.9

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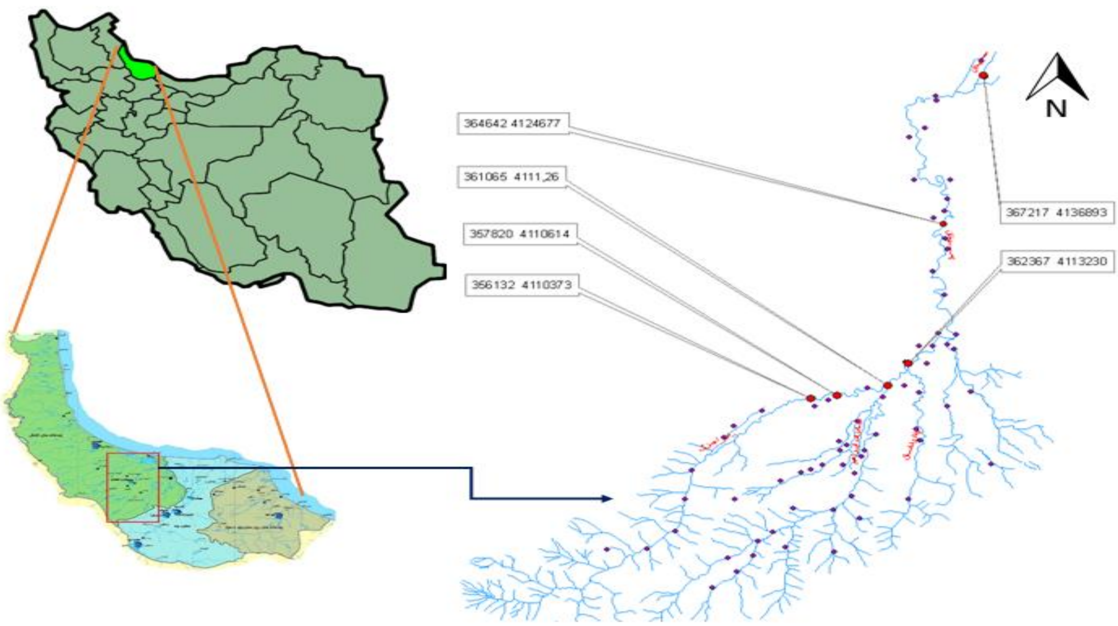

Fig. 1. Location of sampling stations.

The water quality index is determined through the following equation (Eq. 1).

$NSFWQI = \Sigma w_i q_i$ Equation 1

Where w_i is the weight factor of each parameter, and qi is the index calculated from each graph (100-1)

In calculating the NSFWQI based on the above-mentioned formula, after measuring the required parameters, two factors of the weight and quality of parameters are taken into consideration. In the current study, through using the online software of NSFWQI calculator, a numerical value for the NSFWQI is obtained for each station by placing the value of each parameter in the mentioned software. The value of the index was calculated for each parameter, and eventually, the index was calculated for each station by obtaining the average of the values (Table 3). Finally, the resulting number was used to determine water quality, as presented in Table 4 (Mohammadi *et al*. 2008).

Table 2. Measuring methods, device models, and manufacturers.

parameters	Devices and Methods
TSS	Standard Method (Memmert oven 105 ^{0}C)-Method No. D2540
pH	Metrohm pH meter(Switzerland)- Method No. 4500-H^+B
EC	WTW - Inolab model (Germany)
DO	Winkler method (standard titration, iodometry) – BIOSKIEL Method No. 4500-O-B
Water temperature	Mercury thermometer
BOD_5	Manometry – LIEBHERR Incubator

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TDS	WTW - Inolab model (Germany) Method No. 2540 C
Turbidity	TurbiDirect- Lovibond model Method No. 2130 B
COD	OPEN REFLEX Method No. 5220B
PO_4^{3+}	Spectrophotometry- HACH - Model DR5000 Method No. 4500
NO_3^-	Spectrophotometry- HACH - Model DR5000 Method No. 4500 NO_3^-
Fecal Coliform	MPN method (nine tubes)

Table 3. The weight ratio of water quality factors (Mirzaei *et al.* 2016).

Factor	**weight**
Dissolved oxygen	0.17
Fecal coliform	0.16
pH	0.11
BOD	0.11
Temperature changes	0.10
Total phosphate	0.10
Nitrate	0.10
Turbidity	0.08
Total solids	0.07

RESULTS

Nine parameters were measured to assess the water quality in Pasikhan River using NSFWQI (Table 5). According to the results, the lowest pH (8.08 ± 0.11) was measured at Station 6, while the maximum average (8.20 ± 0.08) at Station 2 (Fig. 2). The minimum average of turbidity was recorded in spring, while its maximum in winter (Fig. 3). The results showed that the minimum average of turbidity among stations was 11.08 ± 3.40 NTU in Station 3, while the maximum (59.28 ± 51.75 NTU) in Station 4.

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Table 4. Water quality ranking, using water Quality Index (Mirzaei *et al.* 2016).

Quality based on the numerical indicator	Value for the indicator	classification of water resource
Excellent	91-100	(I) Normal mode, if use it for drinking water supply does not need to be refined, perfect for Fisheries and aquatic sensitive species
Good	71-90	(II) To supply drinking water needs to be treated using conventional, suitable for sensitive fish and aquatic species, suitable for recreational purposes such as swimming
Fair	51-70	(III) If you use it to meet the drinking water needs to be treated is advanced, suitable for Fisheries and Water-resistant varieties, suitable as drinking water Pets
Suitable or quite weak	26-50	(IV) Suitable for irrigating agricultural land
poor	0-25	(V) Gets involved Not suitable for any of the above-mentioned

Table 5. Determination of water quality (WQ) of sampling stations in different seasons based on NSFWQI.

Station	Autumn		Winter		Spring		Summer	
	WQ	NSFWQI	WQ	NSFWQI	WQ	NSFWQI	WQ	NSFWQI
1	Medium	54	Medium	54	Medium	70	Medium	56
2	Weak	49	Medium	58	Medium	62	Medium	56
3	Medium	62	Medium	59	Medium	59	Medium	58
4	Medium	53	Medium	52	Medium	57	Weak	46
5	Medium	53	Medium	61	Medium	60	Weak	49
6	Medium	51	Medium	62	Medium	59	Medium	51

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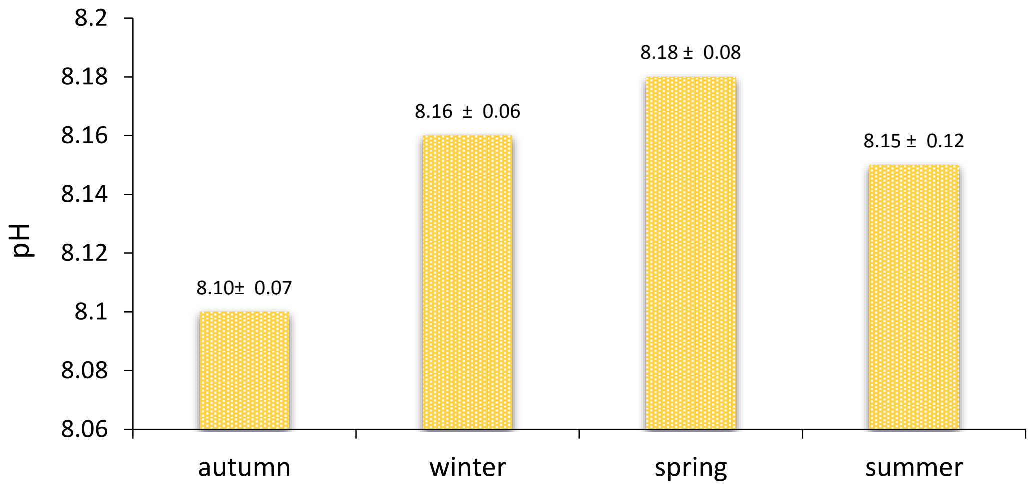

Fig. 2. The averaged pH in Pasikhan River during different seasons (2015-2016).

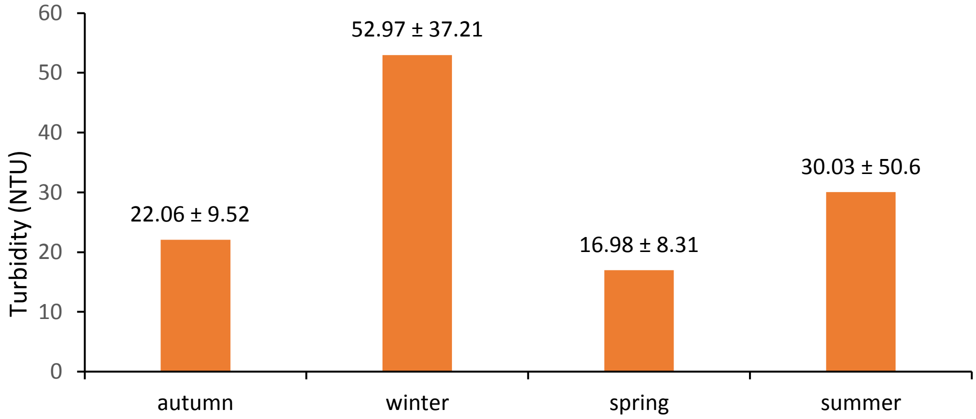

Fig. 3. The averaged turbidity in Pasikhan River during different seasons (2015-2016).

As shown in Fig. 4, the minimum and maximum nitrate concentrations were recorded in the summer and autumn, respectively. Besides, the highest averaged nitrate (2.95 ± 0.65 mg L^{-1}) was observed at Station 4, while the lowest (1.38 ± 0.84 mg L^{-1}) at Station 6. The lowest and highest averages of phosphate were recorded in winter and summer, respectively (Fig. 5). Moreover, the minimum averaged phosphate concentration was 1.08 ± 0.74 mg L^{-1} at Station 1, while the maximum (2.09 ± 1.75 mg L^{-1}) at Station 2. The lowest and highest averaged fecal coliform were observed in spring winter, respectively (Fig. 6). It was also true for the lowest averaged fecal coliform (1807.50 ± 722.65 MPN100 mL^{-1}) at Station 3, and the highest (6332.50 ± 5422.87 MPN 100 mL^{-1}) at Station 6.

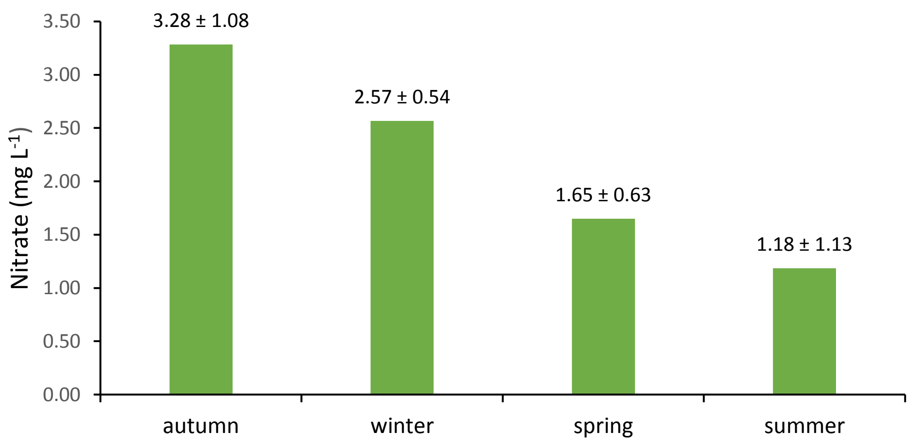

Fig. 4. The averaged nitrate in Pasikhan River during different seasons (2015-2016).

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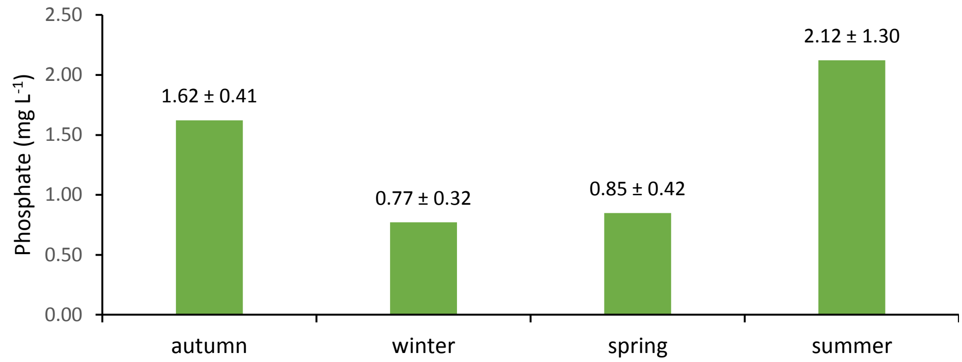

Fig. 5. The averaged phosphate in Pasikhan River in different seasons (2015-2016).

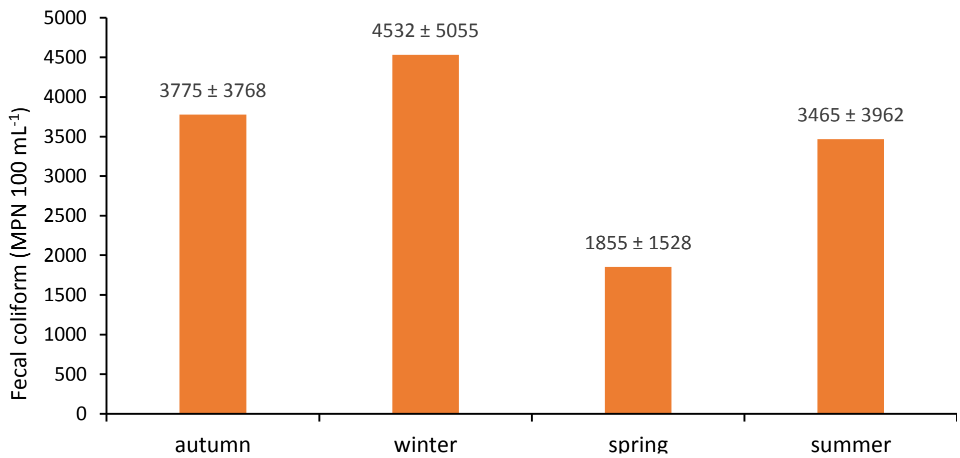

Fig. 6. The averaged fecal coliform in Pasikhan River during different seasons (2015-2016).

The lowest averaged BOD was recorded in winter, while the highest in autumn (Fig. 7). Besides, the highest averaged BOD (6.25 ± 6.18 mg L^{-1}) was recorded at Station 2, while the lowest (2.75 ± 2.36 mg L^{-1}) at Station 1. The lowest and highest averaged amounts of DO were recorded in summer and spring, respectively (Fig. 8). Also, the highest averaged DO was 8.20 ± 1.67 mg L^{-1} at Station 3, while the lowest (6.67 ± 1.37 mg L^{-1}) at Station 6. Furthermore, the lowest averaged TS was in autumn, while the highest in summer (Fig. 9). It was also true for the highest averaged TS (469.03 ± 260.59 mg L^{-1}) at Station 6, and the lowest (283.25 ± 68.75 mg L^{-1}) at Station 1.

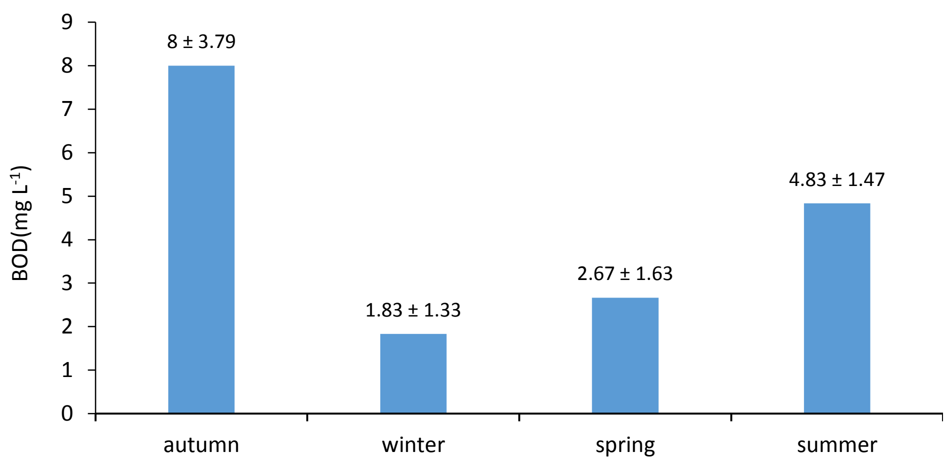

Fig. 7. The averaged BOD in Pasikhan River during different seasons (2015-2016).

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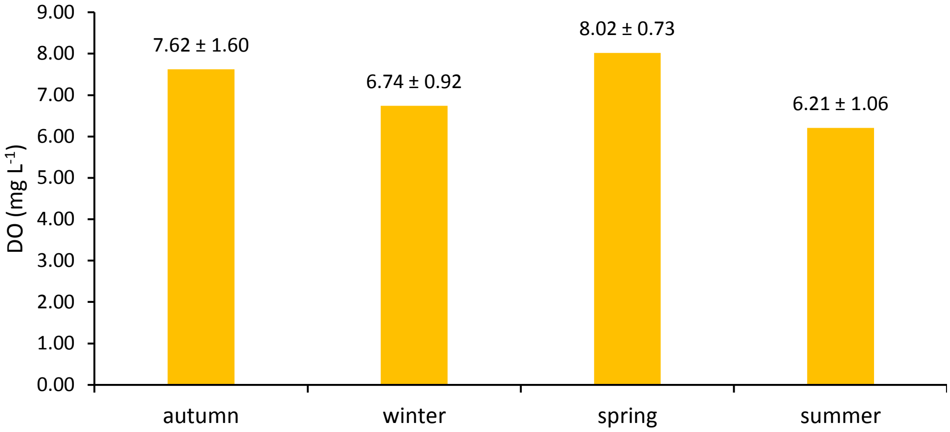

Fig. 8. The averaged DO in Pasikhan River during different seasons (2015-2016).

The results showed that water quality index (NSFWQI), at different stations were fluctuated between 46 and 70. The lowest NSFWQI among all stations was 46.00 at Station 4 in summer which categorized as a bad water quality, while the highest was 70.00 at Station 1 in spring as a medium quality. In addition, the lowest averaged NSFWQI was 52.67 ± 4.72 in summer, while the highest was 61.16 ± 4.62 in spring (Fig. 10). Besides, the lowest annual averaged NSFWQI among stations (52.00 ± 3.94) was recorded at Station 4, while the highest was 59.50 ± 1.50 at station 3 (Fig. 11).

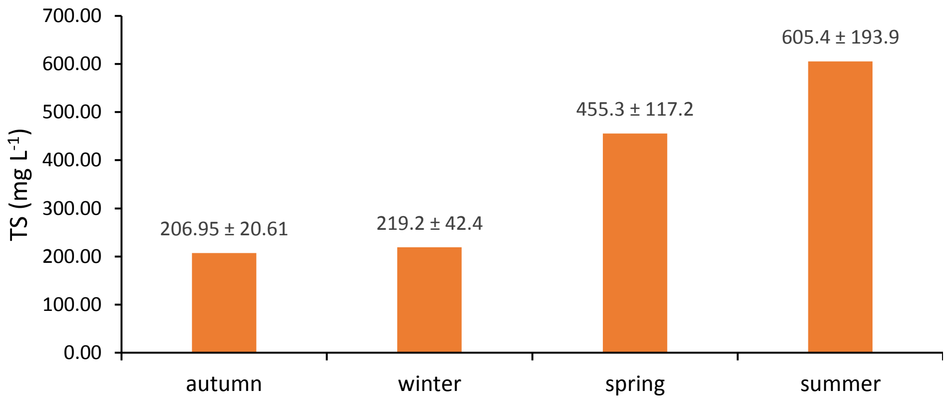

Fig. 9. The averaged TS in Pasikhan River during different seasons (2015-2016).

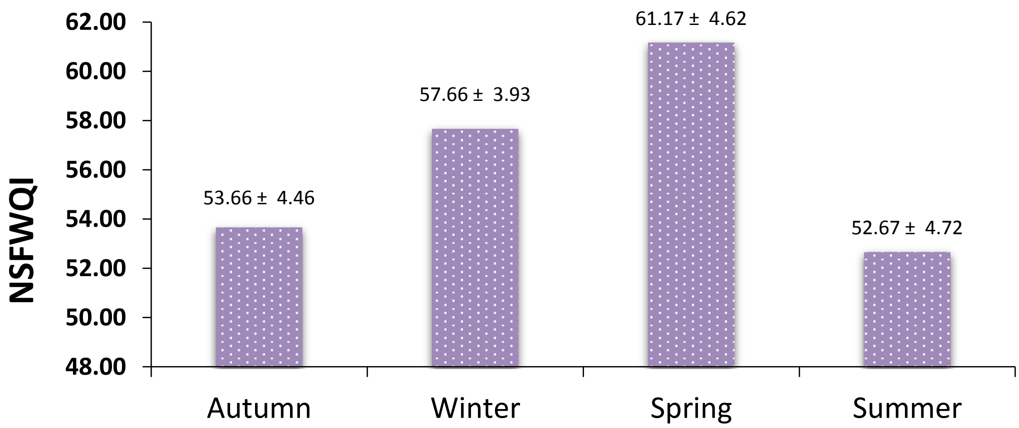

Fig. 10. The averaged NSFWQI measured at all stations in different seasons (2015-2016).

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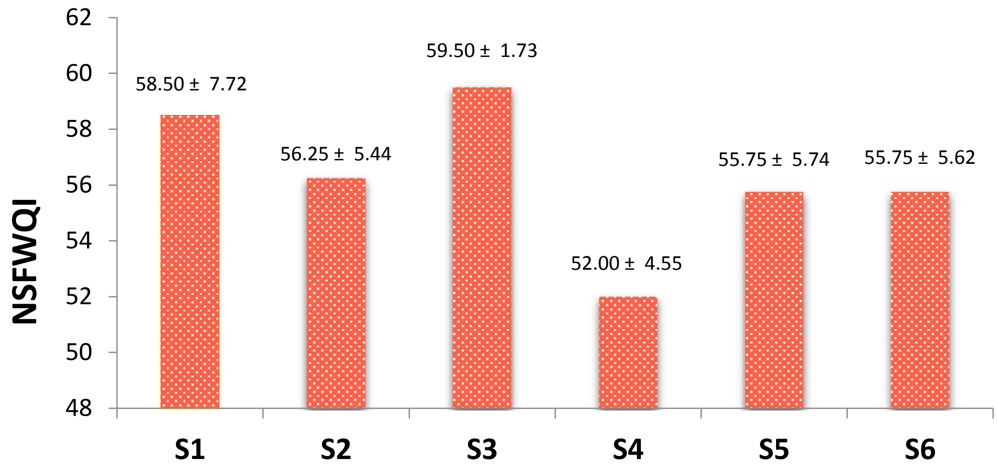

Fig. 11. The averaged NSFWQI values measured at the studied stations throughout the sampling period (2015-2016).

DISCUSSION

In this study, it was found that alterations in water quality index (NSFWQI) at various stations were significantly different from each other and did not exhibit a certain pattern of increase or decrease. It was also found that the range of NSFWQI in Pasikhan River was between 46 and 70, hence between the medium and poor water quality, in line with the results obtained by other authors working on Gargar River (Tahmasebi *et al.* 2011). It was also found that the water quality of Pasikhan River was the best (averaged 61.17 ± 4.62) in the spring and the river enjoyed its highest quality. In contrast, NSFWQI reached 52.67 ± 4.72 in summer exhibiting the lowest quality among the all studied seasons which may be due to the penetration of agricultural runoffs into the river following increased farming activities, increased water temperature because of reduced water flow and less dissolved oxygen, as well as increased turbidity and TS. In a study by Abdul Zali *et al*. (2015) on the water quality of Kinta River (Perak, Malaysia), increased agricultural activities, and also in another study by Madadinia *et al*. (2013) on Karoon River in southwest of Iran, upraising in turbidity and TS were reported as the reasons for the deterioration of water quality. In our study, Station 3 with NSFWQI of 59.50 ± 1.50 and Station 4 with 52.00 ± 3.94 had the maximum and minimum water quality indices. In Station 3, the dropped phosphate and nitrate concentrations while elevated DO level may be due to inflowing Imamzadeh Ebrahiam River into Pasikhan River, enhancing the quality of the latter one. At Station 4, high levels of sand and gravel removal from riversides increased water turbidity. In addition, the sewage discharging from residential parts beside the river, as well as that of paddies of the rural areas around the river elevated the amount of nitrate and phosphate and thus reduced the water quality of this station. In a study on Zarivar Lake in Iran, it was reported that the rural wastewater affects the water quality (Ebrahimpour & Mohammadzadeh 2013). However, in another study on Ciambulawung River (located in Banten Province, Indonesia), it was concluded that the communities living in the river did not exhibit negatively effect on the reduced water quality (Effendi *et al.* 2015). Usually, river pollution will be elevated toward downstream. However, we did not observed it in the studied area, and even in some seasons bacterial contamination was less in the last station, compared with other stations. This finding may be due to self-purification of rivers which is in agreement with the results of studies on Cheshmeh Kile River (Abbaspour *et al.* 2013), Gargar River (Tahmasebi *et al.* 2011), Oshmak River (Khara *et al.* 2011) and also on the Manzars and Gadamer Rivers in France (Sanchez *et al*. 2007). Generally, in the current study, the average water quality index in all stations of Pasikhan River was in the category of medium quality, similar to the results obtained on the Ogan River in South Somatra (Yulistia & Hermannsyah 2018). On the other hand, the results on Bahmanshir River based on NSFWQI, exhibited that it was suitable for agricultural uses (Moradi Majd *et al.* 2017). In addition, during a study on Langroud River in northwest of Iran, it was found that the river water was not suitable for drinking (Kazemi *et al.* 2018) and in another study on Zain-gol River in Iran, according to the NSFWQI, the water quality was suitable for agriculture, but not for drinking (Sadeghi *et al.* 2015). On the contrary, the results obtained on the quality of drinking water of Shiraz City in Iran during 2011-2015 (Bagherpour & Shooshtarian 2018), on Pasikhan River (Aghyani *et al.* 2013) and on Sefidroud River (Mirmoshtaqy *et al.* 2011) were different from our results. Finally, according to our results, in general, the water of Pasikhan River could be placed in the category of medium quality. This water is

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suitable for agriculture and drinking of domestic animals. However, if intended to be used as human drinking water, it requires advanced treatments.

CONCLUSION

According to the measured physicochemical parameters and calculated average water quality index (NSFWQI), the Pasikhan River water in all seasons and at all stations displayed medium quality that is suitable for agriculture and drinking of domestic animals but not for human drinking. Totally, based on the results of these indicators in different seasons and stations, the impact of discharching residential and agricultural wastewaters and also sand and gravel removal on the river was quite apparent.

DECLARATIONS

It is confirmed that work has not been published, not under consideration for publication elsewhere, approved by all authors and, if accepted, it will not be published elsewhere in the same form, in English or in any other language.

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ارزیابی کیفیت آب رودخانه پسیخان، شمال ایران با استفاده از شاخص کیفیت آب (NSFWQI)

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چکیده

شاخص‌های کیفیت آب از جمله روش‌های کنونی برای پایش رودخانه‌هاست. در میان شاخص‌های کلی کیفیت آب، استفاده از شاخص کیفیت بنیاد ملی بهداشت (NSFWQI) در یک بازه زمانی کوتاه منجر به نتایج دقیق تحقیق می‌شود. علاوه بر این، طبقه‌بندی کیفیت آب رودخانه در ایستگاه‌های مختلف را با یک عبارت ساده امکان‌پذیر می‌سازد. مطالعه حاضر، با استفاده از NSFWQI به عنوان شاخص کیفیت آب، با هدف تعیین کیفیت آب رودخانه پسیخان واقع در شمال استان گیلان، ایران انجام شد. شش ایستگاه نمونه‌برداری در امتداد جریان اصلی رودخانه تعیین و نمونه‌های آب طی ۴ فصل (از پاییز ۱۳۹۴ تا تابستان ۱۳۹۵) از این ایستگاه‌ها جمع‌آوری شد. ۹ فراسنجه شامل دمای آب، کدورت، کلی‌فرم مدفوع، NO_3^-، TS، PO_4^{3-}، pH، DO و BOD با روش‌های استاندارد اندازه‌گیری شد. بر اساس نتایج، کیفیت آب رودخانه در تمام ایستگاه‌های نمونه-برداری برای تمام فصول در کلاس‌های متوسط و بد طبقه‌بندی شده است. علاوه بر این، نتایج NSFWQI نشان داد که در فصول نمونه‌برداری، حداقل میانگین NSFWQI در ایستگاه چهارم ۳/۹۴ ± ۵۲/۰۰ و حداکثر میانگین NSFWQI در ایستگاه سوم ۱/۵۰ ± ۵۹/۵۰ بود که هر دو در گروه کیفیت متوسط قرار دارند. به طور کلی، مقادیر شاخص کیفیت آب ایستگاه‌ها از ۴۶ تا ۷۰ در فصول مختلف متفاوت بود و بر این اساس، کیفیت آب رودخانه پسیخان در گروه کیفیت متوسط قرار دارد.

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