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Evaluation of Surface Water Quality by NSFWQI Index and Pollution Risk Assessment, Using WRASTIC Index in 2015

Mojgan Mirzaei[a], Eisa Solgi[b*], Abdollrasoul Salman-Mahiny[c]

[a]School of Natural Resources and Environment, Malayer University, Malayer, Hamedan, Iran.
[b]Department of Environment, School of Natural Resources and Environment, Malayer University, Malayer, Hamedan, Iran.
[c]Department of Environment, School of Fisheries and Environmental Sciences, Gorgan University of Agriculture Sciences and Natural Resources, Gorgan, Iran.
***Correspondence** should be addressed to Dr. Eisa Solgi, **Email**: e.solgi@malayeru.ac.ir

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Background & Aims of the Study: Water resources are useful or potentially useful. Uses of water are included agricultural, industrial, household, recreational and environmental activities. The majority of human uses require fresh water. Rivers are parts of this fresh water that play a very important role in the water cycle, acting as drainage channels for surface water. Hence, regular monitoring program and water quality control are the most important strategies to reduce pollution and improve the quality of water. The aim of this study is the evaluation of surface water quality by NSFWQI index and pollution risk assessment, using WRASTIC index in 2015.

Materials and Methods: In this study, the analytical survey, experimental studies and investigation of references in the context of library studies have been used. Water quality data collected from 7 sampling sites during 4 seasons from March to February 2015 and quality parameters including dissolved oxygen, pH, total dissolved solids, biochemical oxygen demand, turbidity, temperature, phosphate, nitrate and fecal coliform were examined by standard method. Data were analyzed by National Sanitation Foundation Water Quality Index. Then WRASTIC index (Wastewater-Recreational-Agricultural-Size-Transportations avenues- Industrial -cover of vegetation) is used for risk assessment in basin.

Results: NSFWQI index results showed that water quality in the river station 1 (Morkan) is located in the middle class and other stations in all seasons have bad quality. The worst situation (bad quality) was related to the bridge Chum and Varzaneh in autumn with an average of 29 and the best quality is relevant to Morkan station in summer with an average of 59. The finding of WRASTIC index represent that watershed is located in high risk class with the value of 70.

Conclusion: Based on the results of this study, the pollution from station 1 toward the subsequent stations have increased significantly and the river water quality has been reduced. In addition, agricultural, industrial activities and population centers are the main causes of Zayandehrud river pollution. Therefore, the management plans to protect of this valuable river is necessary.

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Background

Water quality is fundamental for river health and sustains ecological processes that support native populations of fish, vegetation, wetlands, and bird lives. Improved water sources are essential for environmental protection and development of economic, political, social and cultural in a country (1). River pollution is one of the most important problems of today's world, especially in developing countries that also Iran faces this problem with its four thousand years old civilization (2). Despite water shortages, misuse of water is widespread. Small communities and large cities, farmers and industries, developing countries and industrialized economies are all mismanaging of water resources. In recent decades, increasing population, industrialization and production of a variety of pollutants in urban areas, industrial and agricultural have increased the pollution of rivers. Monitoring and management of rivers water quality is important, because they are more directly exposed to contaminants (3). In addition, since the rivers directly effect on public health (in drinking water) and aquatic life (through the raw water), the assessment of river water quality is very important (4). Surface water is exposed to pollution more than other water. Looking for rain, especially heavy rain, particles of plant, animal, even industrial and toxic transport with water and contaminate the waters (5). High concentrations of natural organic matter may cause the production of harmful compounds in water and human compounds are considered as the biggest portion of natural organic matter (6). Human compounds are considered the most portion of natural organic matter (NOM) found in many surface water sources. High concentrations of NOM may cause harmful compounds in treated drinking water (7). Also, the leachate from a landfill contains a large variety of different substances, both inorganic and organic matter. Therefore, the site of landfill is as an important factor that effect on the water quality (8).

Water quality is the main factor inhibitor of health in human and animals (9,10). Water pollution also plays a big role in the survival of animals, plant, and human. Recognition and assessment of water resource quality is very important in management and optimal use of it (11). Because water supplies are ultimate recipients of contamination derived from various human activities. Most of human activities such as agriculture, food production, industry, nutrition, and housekeeping are dependent on sufficient and proper quality of water (12). Assessment of water quality characteristics is necessary in the planning related to water resources management as well as basin health assessment and management of its changing (13). Protection of water quality is considered as one of the pillars of planning in integrated management of water, particularly in arid and semi-arid area (14). Sometimes the term of 'risk' is used to express vulnerability. If the vulnerability is only express the inherent characteristics of natural environment in order to determine the probability affected by the adverse effects of pollution on the environment. Risk is generally defined by two characteristics: 1. the vulnerability of physical environment and pollutions 2. The threat comes as a result of human activities. These two factors interact with each other.

Water is a source that is faced with different changes over the time and space; also, it is exposed to many hazards such as pollution. In the nineteenth century, human factors were the most important source of water pollution that created several risks in the field of water quality and public health (15). Risk assessment is a logical method to determine the quantitative and qualitative risks and potential consequences of accidents on people, materials, equipment, and environment. Today, the use of risk assessment methods in different industries is growing; so that there are more than 70 different types of quality and quantity risk assessment methods in the world now. These methods are commonly used to identify, control, and mitigate the consequences of risks (16). Given the importance of this issue, yet several studies in order to assess the quality of water resources and water quality parameters and risk assessment of river pollution carried out that mention some of them.

Khara et al (17) examined the quality of Ashmak river water in Gilan province, Iran.

The results of this study showed that the pollution level in the Ashmak river is moderate to high. Parastar et al (18) were evaluated the water quality index of Hiroochaei river in the area of Khalkhal in Iran in 2013 that was based on NSFWQI and WILCOX indices. According to the results of that, the water quality of this river has been reported in a moderate-good range. Dehghanzedeh et al (19) examined the quality of Mehran river in Tabriz, using NSFWQI index and concluded that the water quality was in a bad range. Shokuhi et al (20) evaluated the water quality in Idghamoosh dam with NSFWQI index. The results showed that the water quality is good for different uses. Mirmoshtaghi in 2011 (21) studied the water quality of Sefidrood river by investigation of 20 samples at 5 sampling stations according to NSFWQI index. The re¬sults showed very bad water quality of Sefidrood river during the study.

Also, Liu and colleagues (22) were examined the indicator of pollution in Liu and Xiang rivers that generally the amount of river water pollution in Xiang river was more than Liu river and its quality was lower. Mirmoshtaghi et al (23) examined the quality of Sefidrud river water and concluded that this river is faced with an agricultural and municipal wastewater and industrial effluent that entered to river. So that the contamination of coliform has increased from upstream to downstream stations and use of this water for drinking, agricultural and other expenditure is perilous. Bayati and colleagues (24) examined water quality changes trend in Ahar river and it's possible effect on human health and concluded that three indicators sodium, sulfate and total dissolved solids during the study of 40 years, increasing trend has been observed and total dissolved solids indicator is located in a bad range for human consumption based on standard thresholds. Meftah (25) classified Atrak river based on water quality. Classification of water quality of this river has studied by NSFWQI, BCWQI index and simple management methods. The results showed that all stations have bad conditions except one of them. Hosseiniyan and colleagues (26), Saadati and colleagues (27), Jamshidiyan and Alavimoghadam (28), Basir and Nabavi (29) and Mirzaei et al (30) used NSFWQI index to classify different rivers water quality and by measuring the required parameters, the quality of the rivers were classified based on annual quality index. Their results showed the effectiveness of this method. Samantray and colleagues (31) examined the quality of Mahanadia and Athavabanki rivers in India, using NSFWQI index. The results showed that the water quality based on the indicators has declined due to human activities and industries.

Karoon water quality among 2001-2006 based on WQI index indicated that Karoon river water quality in Ahvaz is in the range of medium and threatened (32,33). Madadinia and colleagues assessed the water quality of Karun river in Ahvaz range, using NSF's quality index in 2014 and concluded that Karoon water is not suitable for irrigation and drinking, but it is better to preserve an aquatic life (34). Bateni and Soffianian (35) evaluated Zayandehrud river water quality, using WQI index that the results indicated that this river has no appropriate conditions in terms of water quality status. However, Choom bridge, Ziyar bridge, Ajiye bridge and Varzaneh stations always set bad and very bad qualitative classification.

Ranjbar Jafarabadi and colleagues (36) examined the causes of river pollution in Zayandehrud river and it's quality, using their NSFWQI and based on this index, the river was in the middle class. Niknia (37) evaluated the pollution risk assessment in Chaharbagh basin by WRASTIC (Wastewater-Recreational-Agricultural-Size-Transportations avenues-Industrial -cover of vegetation) index. Results of index showed that the risk of pollution is 50 in this basin and this value of risk represents middle pollution risk due to human activities for this hydrological environment.

Rahimi and colleagues (38) evaluated the quality of water entering into the wetland, using risk assessment index and vulnerability of water resource pollution by WRASTIC index. Consequently, the index reflects the large impact of basin components in wetland pollution.

Ghorbani and Azimi (39) evaluated the pollution risk assessment in Golestan basin of Khorasan province, using WRASTIC model that the risk derived from the calculation of this index indicate a high risk caused by human activities for this hydrological environment.

Water quality in each area reflects the effect of different factors such as geology, climate and human pollution sources and monitoring the quality of water resources often produce complex data which are contain rich information about the behavior of water resources and they need to appropriate methods for analysis and interpretation. Indexes are appropriate and simple tools to determine the status and water quality conditions which incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water system with number. This number classified as a relative scale from poor to excellent that represent water quality.

Aims of the study:

The aim of this study is evaluation of surface water quality, using NSFWQI index and pollution risk assessment by WRASTIC index in 2015.

Materials & Methods

Study area

This study has been carried out in the Zayandehrud basin which is located in west-central Iran with semi-arid region (latitude 31°12'N, longitude 50°02'E). Zayandehrud is one of the most important rivers of the central plateau of Iran. Zayandehrud watershed extends over a total area of 41500 km2. Zayandehrud River flows in this watershed with a length of about 350 km from west to east. This river is originated from the Zagros mountains in the west of Isfahan province and ends in Gavkhuni wetland. Life of Isfahan area is dependent to Zayandehrud river and thus maintain the quality of drinking water, agriculture, industry and preserve the aquatic environment are very important. In Figure 1, Zayandehrud basin with the main and tributary rivers and studied hydrometric stations are shown.

Method of study

Water quality indices are one of the simplest methods to determine water quality conditions that are helpful for the selection of an appropriate treatment technique to meet the concerned issues (40).

Among these indices, national sanitation foundation water quality index (NSFWQI) has been implemented in many locations of the world which its calculation, different physical, chemical and biological parameters are measured including dissolved oxygen, PH, all of the solids, the required biochemical oxygen, turbidity, temperature, phosphate, nitrate and excremental coliform. This index is easy to calculate and has been a popular index (41). This research is an experimental study. In this study, NSFWQI index is used for monitoring and assessing water quality of Zayandehrud river.

Data Collection

Water quality data collected from 7 sampling sites during 4 seasons from March to February 2015. Since river water was not open and cannot be sampled monthly, sampling was carried out quarterly. In each station, water quality parameters including dissolved oxygen, pH, total dissolved solids, biochemical oxygen demand, turbidity, temperature, phosphate, nitrate and fecal coliform was measured.

Data analysis

National Sanitation Foundation Water Quality Index (NSFWQI) calculation

The parameters of temperature, soluble oxygen, and in-site PH are measured. The level of soluble oxygen is calculated with the DO-meter device- Winlab model. PH and temperature are also calculated, using the PH-meter- Multi 340 i model which are all portable. The turbidity of the samples is also read in laboratory, using the turbidity-meter device- Hach model 2100N made in U.S.A, and the parameters of TS, phosphate, Nitrate, BOD and fecal coliform are also measured based on the methods available in the standard book of method.

In calculating the index of NSFWQI, according to the Eq. (1), two factors of the weight and quality of parameters are involved, and in this study, the value of index is obtained for each stationary, using the online software of NSFWQI calculator (Figure 2). In this way, by placing the value of each parameter in the mentioned software, the value of index is calculated for each parameter and finally, the index is determined for each considered stationary or month through obtaining the average of the values. This index has a value between 0 and 100 which rates the water quality to excellent (90-100), good (70-90), moderate (50-70), bad (25-50) and very bad (0-25) situations based on Table 1 (42). This index is a decreasing index (i.e. the index decreases with increasing pollution).

$$NSFWQI=\Sigma W_i Q_i \qquad \text{(Eq. 1)}$$

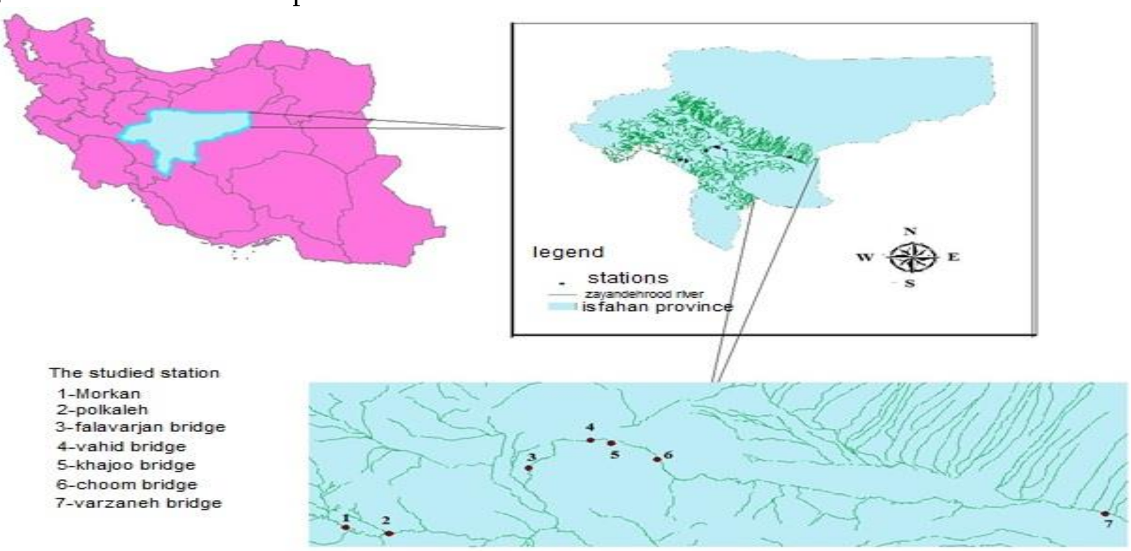


Figure 1) Zayandehrud basin and studied hydrometric stations

Table 1) The guide of the water quality index

The index limit	Water quality	Classification of the type of water resource usage
90-100	Excellent	Having natural state, it has no need to be treated if it is used to provide the drinking water, it is appropriate for training the fishery and water-resistant species.
70-90	Good	If it is used to provide the required drinking water, it requires conventional treatment. Appropriate for fish farming and water sensitive kinds, appropriate for recreative purposes like swimming
50-70	Moderate	If it is used to provide the drinking water, it requires the advanced treatment, appropriate for fishery and water-resistant types, appropriate for the domestic animals as the drinking water
25-50	Bad	Appropriate for irrigating the agricultural lands
0-25	Very bad	It is not appropriate for any of the mentioned usages, and it has only the ability of supporting a limited number of the aquatic animals

To obtain quality parameter (Q), index curves are used that these curves for the various parameters are shown in Figure 3. It should be noted that if the number of fecal coliform colonies is greater than 100,000, the quality index equals 2, if total solids is greater than 500 ppm, the quality index equals 20, if dissolved oxygen is greater than 140 percent, the quality index equals 50, if pH is greater than 12 or less than 2, the quality index equals 0, if turbidity is greater than 100 NTU, the quality index equals 5, if biochemical oxygen demand is greater than 30 ppm, the quality index equals 2, if nitrate is greater than 100 ppm, the quality index equals 1, and if phosphate is greater than 10 ppm, the quality index equals 2.

Required factors and selected weight in NSFWQI index is given in table 2.

Table 2) factors and their weight in NSFWQI index

parameter	unit	weight
Dissolved oxygen	%	0.17
BOD	Mg/lit	0.11
phosphate	Mg/lit	0.10
nitrate	Mg/lit	0.10
temperature	°c	0.10
Total solids	Mg/lit	0.07
Fecal coliform	Most probable number (MPN)	0.16
turbidity	NTU	0.08
pH	-	0.11

Pollution risk assessment of water resources systems, using WRASTIC index

WRASTIC is a method developed to evaluate watershed susceptibility to surface water contamination in any hydrogeological setting based on major watershed characteristics and land uses. It was developed for US-EPA, in 1991, by the American Water Works Association and afterward adapted by NMED/DWB (New Mexico Environment Department Drinking Water Bureau).

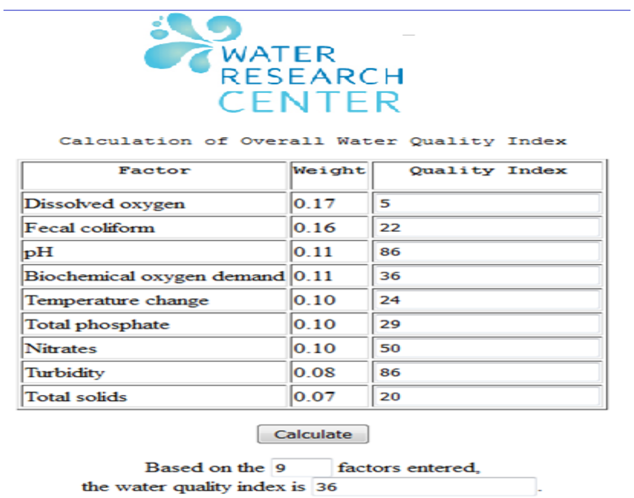


Figure 2) online software of NSFWQI calculator

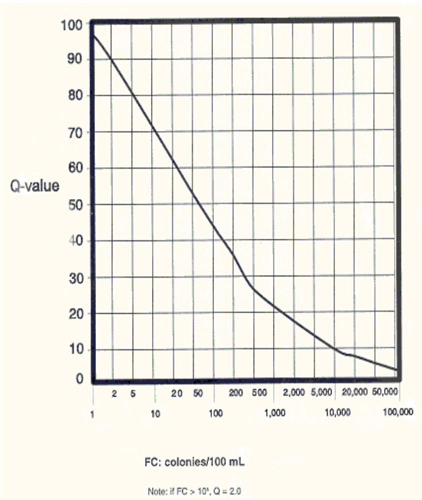
WRASTIC is an acronym for the following parameters: Wastewater discharges (W); Recreational land use impacts (R); Agricultural land use impacts (A); Size of watershed (S); Transportations avenues (T); Industrial land use impacts (I); and the amount of vegetative ground Cover (C).

The equation for determining the WRASTIC Index for any watershed is:

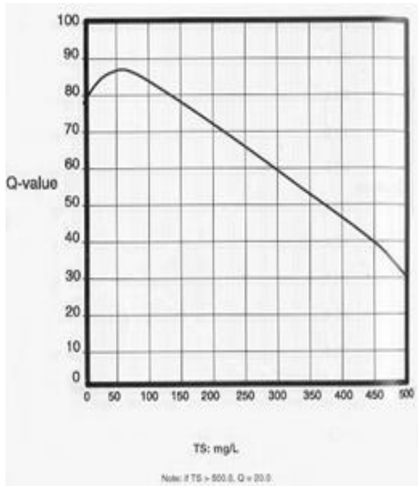
WRASTIC Index = WRWW + RRRW + ARAW + SRSW + TRTW + IRIW + CRCW (Eq.2)

Where: R = Rating factor and W = Weight factor.

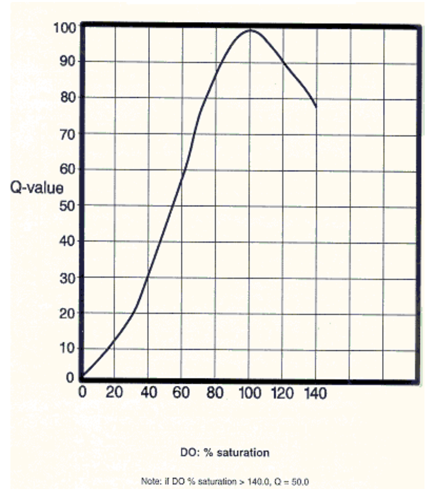
The higher WRASTIC Index, the higher the surface water pollution potential. Professional judgments are commonly applied to refine the WRASTIC Index. WRASTIC index uses very simple features that are weighted considering their influence in surface water pollution. The sensitivity rank to pollution considers four categories, i.e., very high, high, moderate and low sensitivity of the water supply.



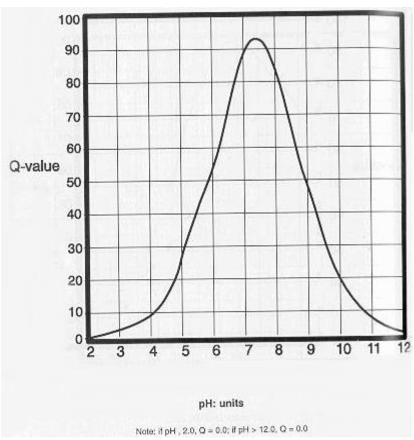
a- curves for fecal



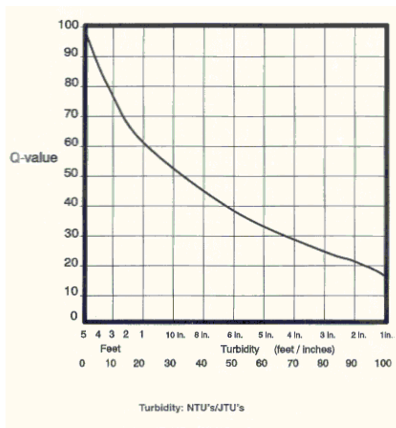
b- curves for total solids



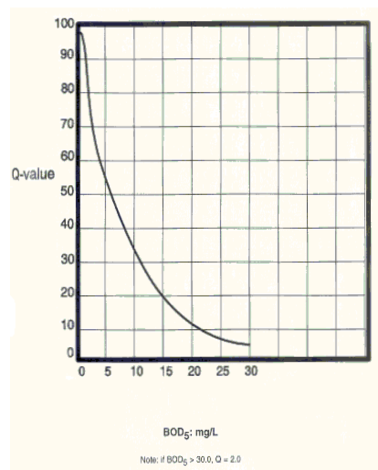
c- curves for DO



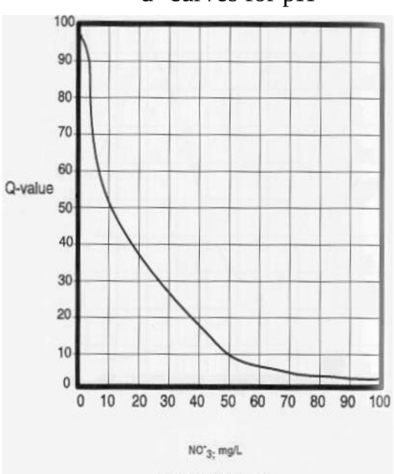
d- curves for pH



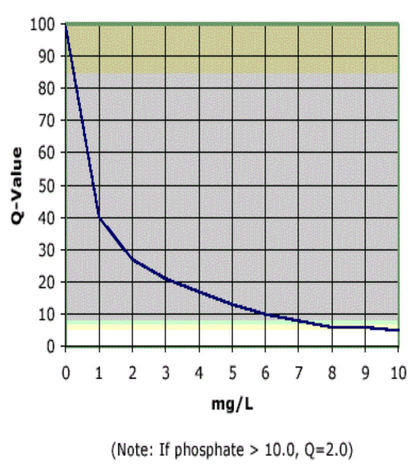
e- curves for turbidity



f- curves for BOD



g- curves for NO_3



h- curves for PO_4

Figure 3) Index curves to determine the quality parameter (Q) in the NSFWQI model

Table 3 shows the parameters of this indicator and its rating and Table 4 shows the amount of index for each risk class.

Table 3) parameters of WRASTIC Index and its rating

parameter	range	rating	weights
Wastewater discharge (W)	Public WWTP effluent introduced into watershed area and private septic systems present	5	3
	Public WWTP effluent introduced into watershed area	4	
	> 50 Private Septic systems present	3	
	< 50 Private Septic systems present	2	
	No Wastewater discharges present	1	
Recreational impact (R)	Motorized activity allowed on water	5	2
	Non-motorized activity allowed on water	4	
	Vehicle Access	3	
	No Vehicle Access	2	
	No Recreational Access	1	
Agricultural impact (A)	5 or more activities present	5	2
	4 activities present	4	
	3 activities present	3	
	2 activities present	2	
	1 activity present	1	
Size of Watershed (S)	> 1942.35 km2	5	
	388.47 - 1942.35 km2	4	1
	155.39 – 388.47 km2	3	
	38.85 – 155.39 km2	2	
	< 38.85 km2	1	
Transportation Avenues (T)	Railway or Interstate avenue through watershed area	5	
	Highway avenues through watershed area	4	1
	State highway or other paved avenues through watershed area	3	
	Unimproved avenues (dirt roads) through watershed area	2	
	No transportation avenues through watershed area	1	
Industrial Impact (I)	Industry has a very large discharge or very heavy impact on surroundings	8	
	Industry has a large discharge or heavy impact on surroundings	6	4
	Industry has a moderate discharge or moderate impact on surroundings	4	
	Industry has minimal discharge and minimal impact on surroundings	2	
	No Industry in watershed	1	
Vegetative Cover (C)	0 - 5 % Ground Cover	5	
	6 - 19 % Ground Cover	4	1
	20 - 34 % Ground Cover	3	
	35 - 50 % Ground Cover	2	
	> 50 % Ground Cover	1	

Table 4) Risk classes based on the WRASTIC index

Range of index	Risk classes
10-39	Low
40-69	Intermediate
70-89	High
90-100	Very high

Results

The results of NSFWQI water quality index

Water quality state of different stations and seasons is presented in table 5 by NSFWQI results.

The results of the risk assessment with WRASTIC index

Seven parameters in WRASTIC Index for Zayandehrud river basin examined and this index was calculated ultimately. Results are presented in Table 6.

Based on WRASTIC index, Zayandehrud basin placed on the class with high risk and this basin is exposed high pollution and vulnerability.

Table 5) The results of water quality evaluation at different stations and seasons using NSFWQI

Season / stations	spring	water quality status	Summer	water quality status	autumn	water quality status	winter	water quality status
Morkan	57	Moderate	59	Moderate	52	Moderate	58	Moderate
Polkaleh	38	Bad	42	Bad	37	Bad	43	Bad
Falavarjan bridge	35	Bad	44	Bad	35	Bad	43	Bad
Vahid bridge	40	Bad	42	Bad	33	Bad	42	Bad
Khajoo bridge	36	Bad	41	Bad	37	Bad	43	Bad
Choom bridge	32	Bad	36	Bad	29	Bad	35	Bad
Varzaneh bridge	35	Bad	34	Bad	29	Bad	36	Bad

Table 6) Calculation of WRASTIC Index for Zayandehrud river basin

studied factors	Determined rate for the study area
Wastewater discharge (W)	Discharge of industrial wastewater into the river network (5)
Recreational impact (R)	Motorized activity allowed on water (in Chadegan and Zayandehrud when the river is full of water) (5)
Agricultural impact (A)	There are irrigation and agricultural development projects in the region (5 agricultural activity) (5)
Size of Watershed (S)	41500 km2 (4)
Transportation Avenues (T)	There are several highways, public roads and railways in the area (5)
Industrial Impact (I)	Industry has a large discharge or heavy impact on surroundings. Wastewater discharge of steel and Dyeing Factory to river network (6)
Vegetative Cover (C)	35 - 50 % Ground Cover (2)
WRASTIC Index for study area	70 (High risk)

Discussion

The Zayandehrud river basin is the most important watershed and a crucial source of water for irrigation, as well as for industries, animal farming, municipal supply, and waste water dilution. Also, this river is a vitally important river for agricultural development as well as domestic water supply and economic activity of the Isfahan province in west-central of Iran (43). In Zayandehrud basin, municipal water utilities, industry such as cement companies, large steel rolling mills, pulp and paper, power plant companies and irrigation-dependent agriculture, all have a high priority of water demands and effect on water quality. Therefore, obtaining the information about water quality in different parts of the river is important.

Quality status assessment in surface water through regular monitoring is foundation of plans to control and reduce the pollution of river landscape. The suitability of water sources for human consumption has been described in terms of water quality index, which is one of the most effective ways to describe the quality of water. Water quality index utilizes the water quality data and helps in the modification of the policies, which are formulated by various environmental monitoring agencies. It has been realized that the use of individual water quality variable in order to describe the water quality for common public is not easily understandable. That's why; Water quality index has the capability to reduce the bulk of the information into a single value to express the data in a simplified and logical form. It takes information from a number of sources and combines them to develop an overall status of a water system (44). In this study, NSFWQI index was used to evaluate water quality. According to the results, the Morkan station is located in a moderate range in different seasons that is consistent with the result of Ranjbar Jafarabadi and colleagues research (36). Other stations are within the range of a bad situation. In fact, because the Morkan station is located in the upstream of basin and there are not industrial activities in the surrounding area of it, the quality of water in this station is better than other stations. In Polkale and Falavarjan bridges, water quality is lower in spring and autumn compared to the summer and winter. In fact, in these areas for the cultivation of autumn, spring and continued use of chemical fertilizers, the amount of non-point pollution increases and the status of water quality would be unsuitable.

The reason of Polkale, Falavarjan bridges and Choom bridge stations pollution is due to the land devoted to agriculture in these areas that is shown in land use map (Figure 4). Also, there are discharge of untreated sewage bypasses that related to the wastewater of some industries around the river in Falavarjan and Choom bridge stations that this finding is correspondence with Javid et al in 2014 that concluded the discharge of numerous factories swages into the river is the main reason of Mojen river pollution (45).

Since Varzaneh station is downstream of the study area, water flow in this area is less than other stations, thus pollution load is increasing in this station. According to the recent drought in Zayandehrud basin, the pollution is increasing. Lack of proper environmental management, control and monitoring on the river and its numerous branches are caused industrialists and land owners in the upstream and downstream of the region without regard to ecological principles and long-term objectives through untreated wastewater discharge of industrial, urban and agricultural are causing the pollution into the aquatic environment of their ecosystems. The causes of river pollution are steel drainage, wastewater of polyacrylamide, wastewater of Simin textile factory, dyeing factories, and Isfahan wastewater treatment plant. According to rapid population growth and the subsequent development of urban and industrial centers around the river, if a quick action is not taken seriously, the pollution in the river bed will threaten human health and other organisms.

Choom and Varzaneh bridges (stations 6 and 7) with NSFWQI index of 29 in the autumn had the lowest water quality that is consistent with research done by Bateni and Soffianian (35). In Varzaneh station, the value of phosphate, nitrate and BOD is very high, therefore, water quality in this station is worse than other station. At Varzaneh station, water is highly polluted due to the industrial, agricultural and municipal wastewater discharge into the river. Indeed, the best condition was related to the upstream and the worst condition was related to the downstream of Zayandehrud river that is similar to the results of Noorbakhsh et al (46) that concluded the best condition was related to the upstream and the worst condition was related to the downstream of Siahrood river.

Vahid bridge station receive the pollution that transmit from upstream to downstream due to industries. In fact, the pollution of Vahid and Khajoo bridges (stations 4 and 5) that are located in the central city of Isfahan is attributed to the place of these stations in residential areas and population centers, urban activity and urban sewage discharge (Figure 4). In Vahid and Khajoo bridges, phosphate and

BOD have increased due to the use of different detergents within city range. In a study which had been done by Mirzaei and colleagues for zoning of river quality in Jajrood river, using NSFWQI index have been obtained similar results (30) that have shown that water quality in the adjacent population centers because of the arrival of microbial contaminants and increased turbidity and suspended solids has decreased.

According to the results of this study, NSF water quality index is a good index for evaluation of the quality of Zayandehrud river water in which it can be used to determine the water quality at designated stations used for a variety of uses. In Samadi and colleagues research that has been done on Morad Beik river water in Hamedan, the results showed that NSFWQI quality index is a good indicator for river zoning (47).

Kumar et al. in a similar study in 2011 to assess the water quality of the Sabaramati river concluded that this index can be a great and applied management tool to study the water quality of rivers (48).

In addition to the factors discussed before, warm climate, low rainfall and river flow reduction during the seasons of study has been effective on the water quality of Zayandehrud river.

Nowadays, important parts of water requirements for various sectors of agricultural, potable, and industrial are supplied from the surface water resources. Population growth and civilization and also, industrial and agricultural developments increased the risk of water resources pollution. So, the application of appropriate methods for the management of surface water quality seems necessary to be considered. In this study, WRASTIC index used to risk assessment of water resource pollution.

Conclusion

Regarding to study results, the river water quality hasnot a good condition. The results of the study showed that the downstream of the river is highly polluted; after passing Isfahan city, the water quality is unsuitable as drinking water supply, agricultural and industrial uses.

The worst situation (bad quality) was related to the Chum and Varzaneh bridges in autumn with an average of 29 and the best quality is relevant to Morkan station in summer with an average of 59.

Also, the finding of WRASTIC index represent that watershed is located in high risk class with the value of 70. Considering the high risk of pollution, conservation of the Zayandehrud watershed is essential.

The NSF water quality index is an appropriate and general index for classification of Zayandehrud river water quality. In this study, river water quality can be characterized by means of this index for different kinds of applications. Furthermore, assignment of the appropriate plans for prevention of disposal pollutants to the river watershed, will lead to enhancement of its water quality. It can be seen that water quality of river system deteriorates slightly from winter season to summer season. This could be due to the fact that the microbial activity reduced due to low temperature, thereby keeping DO level at a very satisfactory range during entire winter season. Also, during summer, the water quality deteriorates on account of the increase in microbial activity as well as increase in pollutants concentration due to the water evaporation. Application of NSF Water Quality Index in this study has been found useful in assessing the overall quality of water and to get rid of judgment on quality of the water. This method appears to be more systematic and gives comparative evaluation of the water quality of sampling stations. It is also helpful for public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

With regard to the subject, it can be concluded two basic results: 1- population loading and great activity in basin of this river and also urban rapid development, life functions, urban and industrial activity are the most basic sources of river pollution and yet wasteful use of chemical fertilizers and pesticide, discharge of urban, rural sanitation and continues solid waste discharges to the river, warm climate and low rainfall increase river pollution. Thus, human factor is the main cause of pollution in the river. 2- In addition to human factor, natural factors such as low rainfall, seasonality of precipitation, water use for agricultural and industrial purposes, high water harvesting, development of agricultural land at the expense of harvesting of natural land, degradation of vegetation and hardening the land surface increased physical and chemical pollutions of river and impaired bioavailability and biological of it.

In general we can say that with current situation and the continuing droughts, if this river will not be managed, turn in to a disaster.

Also, according to obtained risk levels for Zayandehrud basin with WRASTIC Index (number 70), this basin is vulnerable to pollution and high vulnerability due to human activities on the hydrological environment. The reasons are the high volume of discharged sewage into the basin, high levels of agricultural, recreational and industrial activities in the region, large size of the watershed and the existence of transport routes. Water shortage and the adverse effects of human activities and land use change may also exacerbate the problem. Accordingly, monitoring and controlling human activities in the watershed scale in order to improve ecological conditions and water resources of the region will become necessary.

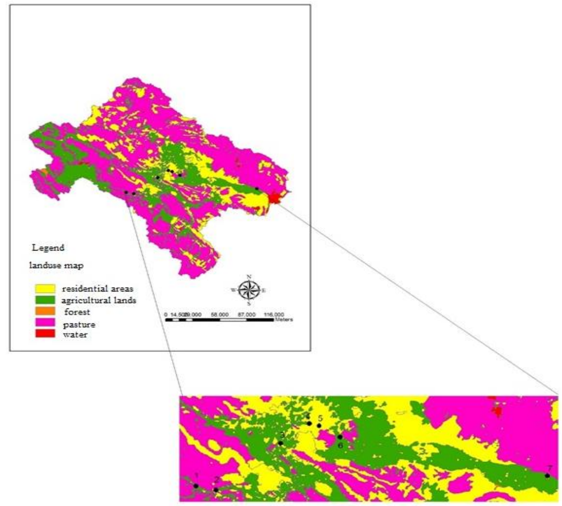


Figure 4) land use map in Zayandehrud basin and location of studied stations

Recommendations:

By examining the contaminants in the river we can say that: 1. increasing the efficiency of wastewater treatment plant 2. Change the location of wastewater discharge 3. Wastewater treatment plants around the city that is inserted directly into the river are necessary actions to reduce the pollution of this ecological biome. Generally, pollution sources in different stations has been reduced river water quality that appropriate strategies to prevent the entry of contaminants including strict guidelines and public participation will help to improve the quality of its water.

About WRASTIC Index, this method could be improved concerning the adopted features using sub-ranges and ratings more suitable.

Footnotes

Conflict of Interest:

The authors declared no conflict of interest.

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