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Survey of the Water Quality of the Bahar County Streams (Iran) by NSFWQI

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ABSTRACT

In Bahar County (Iran), rivers are among the important sources of water for the agricultural sector. Therefore, this research evaluated the parameters of temperature, pH, Total Dissolved Solids (TDS), turbidity, nitrate, total phosphate, dissolved oxygen (DO), Biological Oxygen Demand (BOD_5), and fecal coliform at five stations for five months (from February 2015 to June 2015) to determine water quality in the rivers. Based on this evaluation, the NSFWQI index was calculated and, finally, the routes of the rivers were zoned. The best water quality was recorded at Station Number 3 with the NSFWQI Value of 80 in January, and the worst at Station Number 5 (latgah) with the NSFWQI Value of 37 in June. Based on the mean NSFWQI indices, water quality was Medium at Stations Number 1, 2, and 4, good at Station Number 3, and bad at Station number 5.

Key words: *river, Water quality, wastewater, pollution, NSFWQI*

Introduction

Water is an important component of natural resources, which plays a very significant role in the life and health of humans and other living beings. Although water is an abundant material in the Earth and more than 70% of Earth's surface is covered by water, however, despite the huge volume of water, only 2% of Earth's waters encompass fresh water, and the rest is saline water due to dissolved variety of salts. Over 90% of the aforementioned age of fresh water occurs frozen and located at the two poles of the Earth and inaccessible to the mankind. Our country, Iran, with an average rainfall of 250 ml, is considered an arid and semi-arid country. The majority of the fresh waters of Iran stream as flowing waters in rivers, which is one of the important development issues in various aspects. The use of the country's waters, especially surface fresh waters is increasing because of population growth, expansion of industrial, agricultural and recreational activities on one hand, and on the other hand, their quality is at risk with the entry of contaminated effluents from various activities (Khatami, 2011). Surface waters are exposed to pollution more than other waters. Following the rainfall, especially heavy precipitation, different plant, animal and industrial and poisonous particles are transported by water and pollute the waters. By pouring contaminated water resulting from industrial everyday life into the water streams, man causes increasingly contamination of waters (Meftah halaghi *et al.*, 2005) Surface water quality in different regions involves various changes due to the diversity of geological formations and structures and hydrological factors. Investigating seasonal changes of surface water quality is an important aspect of the evaluation of temporary changes in river pollution due to point and non-point sources (Ouyang *et al.,2006)*. Therefore, understanding and evaluating the quality of water resources is very important in their management and optimal use. Today, for monitoring and quality control of surface waters, the water quality indices are used. By simplifying and reducing the raw and initial data, the qualitative indices show water quality changes over time and space in addition to explaining the water quality (Nasirahmadi *et al.*, 2012). In the meantime, monitoring and evaluation of rivers water quality using the classification of water quality index of NSFWQI (National Sanitation Foundation Water Quality Index) leads to providing more accurate and faster results and predictions, and makes it possible to present and classify the rivers water quality in different stations with simple words (Hoseini *et al.*,2013). Water Quality index based on a survey of a large number of professionals with diverse expertise in the area. They first introduced about 35 pollution parameters, and then chose about 9 parameters to develop the main index according to the experts. It included the parameters of temperature changes, total dissolved solids (TDS), total phosphorus, turbidity, pH, fecal coliform (FC), nitrate,

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dissolved oxygen (DO) and BOD_5. After measuring the above characteristics, the sub-index of each is obtained from the conversion curves. Using these curves, the parameters are converted to 0-100 standards. In this method, for calculating the final index, each of the sub-indices derived from the respective curves is multiplied by its weight factor. According to the relevant formula, the final index is obtained by summing them (Jafarabadi & Amoushahi, 2010).

Using the NSFWQI Index is common and many studies have been done in this area. Galin Sharifdini *et al.* (2014) used the NSFWQI index to assess the water quality of Dohezar River, Tonekabon. The results of this study indicated that during drought period, all three upstream, downstream and the in-between areas of the river were in a good quality range, while in the wet period, the upstream area was in the good range and the downstream and in-between were in the mid-range. Finally, it was concluded that the greatest effect of pollutions is caused by fisheries workshops8. Based on the NSFWQI qualitative index in Hiro Chaiee River, Parastar *et al.* (2013) showed that the best water quality status was related to the first station with value 74 (good quality class) in January 2009 to February 2009, while the lowest value of the index was related to the third station with the quality index of 53 (Medium quality class) in July, to August, 2008. The results showed that the water quality in the upstream (first station) was in a good situation due to non-entry of sources of pollution. However, by gradual discharge of Khalkhal city sewage into the river, the water quality in the downstream of the city (the second and fourth stations) has declined. Effendi *et al.* (2015) collected samples from three selected stations using the NSFWQI index and pollution indicator to determine the water quality of Ciambulawung River and evaluated the qualitative parameters. The results of this study showed that the river water quality in all three stations is in a good status based on the pollution indicator, and the NSFWQI index value of the river was calculated in the range of 87-88. Shah and Joshi (2015) also used the WQI water quality index to assess the quality of Sabarmati River in India. It was found in this study that human activities and the disposal of sewage in the river have strongly affected many water parameters. The results from the calculation of WQI quality index for the river indicated that the first, second and third stations were at the bad quality class, good quality class and the good to excellent quality class, respectively. Amit *et al.* (2014) to determine the physicochemical properties of the river water samples, two stations were selected in 2010-2013 Based on the 7 parameters (pH, BOD, DO, total phosphorus, total hardness, total solids and nitrate), the NSFWQI Index was calculated for the river. It was concluded in the study that the Chambal river water quality is appropriate for drinking purposes, and the quality of the river water is good. The study also found that the pollution level of Chambal River has not changed from 2010 to 2013.

Since water quality and quantity strongly matters to the human being and monitoring and mapping water quality need to be considered as an important variable in planning, thus, the present study was conducted with the aim to determine water quality along the rivers of Bahar County in the selected stations by using NSFWQI index.

Materials & Methods

Study area

The Bahar County, with an average elevation of 1735 m above sea level, is one of the nine counties in Hamedan province with an area of 1334 km2, which encompassed about 7% of the province's area. The County is located between 34° 47' N to 35° 10' N latitude and 48° 8' E and between 48° 32' E longitude in the west of Hamedan province in Iran. Naturally, the County has an arid climate and its rainfall regime is of Mediterranean climate type (According to the economic, social and cultural brief report of Bahar County, Management and Planning Organization of Hamedan). The surface waters of Hamedan province are divided to Qarechai and Gamasiab watersheds. The province's rivers are generally fed by snow and rain wet seasons. The important rivers of the province are divided into two groups, the first north and East Rivers of Alvand Mountains and the second of the south and southwest rivers of Alvand Mountains. The northern rivers are often seasonal and water fluctuations in them are often very frequent. Most of the rivers in the north and southeast join to Qarechai River.

Methodology

The present study was performed for 5 months from February 20, 2015 to June 21, 2015 on rivers of County of Bahar, Hamedan province. In this study, the water quality of the regional rivers in 5 selected stations was monitored and evaluated using the NSFWQI index.

Studied stations

The stations were selected due to the location of polluting sources, the possibility of sampling and access routes of the 5 stations in the rivers of Hame Kasi (S1), Saleh Abad (S2), Bahadorbeig In 1970, with support from the American National Health, Brown *et al*. (1970) provided a reduction (S3), Qareh aghaj (S4) and Siminehrood (S5) in Latgah village. Then, the geographical location of the target points was determined by GPS. Table 1 shows the geographical coordinates of the selected stations. The positions of the studied stations are also shown in Figure 1.

Table 1: Sampling location coordinates in Bahar County (Iran)

Station	Latitude (East)	Longitude (North)	Altitude (m)
S1	34° 57' 59.856"	48°10' 52.632"	2053
S2	34° 55' 18.12"	48°19' 46.194"	1807
S3	34° 57' 14.178"	48° 20' 20.538"	1970
S4	35° 2' 57.618"	48° 18' 7.722"	1885
S5	34° 59' 8.99"	48° 32' 0.312"	1705

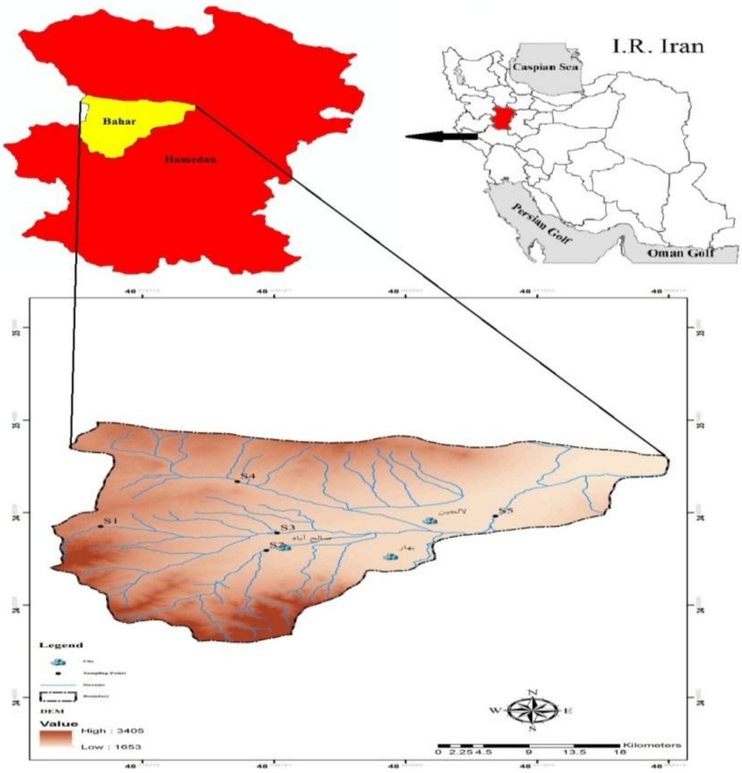

Figure1: Map of study area, waterways network and the position of sampling sites

Sampling and analysis of samples

In present study, according to the Instruction for the surface water quality monitoring (running waters), Publication No. 522, Vice President of Strategic Monitoring, a systematic or regular sampling method – collecting samples at regular and equal one-month intervals and similar locations was used. The samples were collected in the middle of each month and before noon from the middle of the river at selected stations and transferred to the laboratory under controlled conditions. In each station, the quality parameters including, temperature, total dissolved solids (TDS), total phosphorus, turbidity, pH, fecal coliform (FC), nitrate, dissolved oxygen (DO) and Biological Oxygen Demand (BOD_5) were measured according to the standard methods procedures (APHA, 2005). In the present study, the parameters were measured by the following methods:

- Dissolved oxygen: Titration with alkali iodide (according to the 4500_O_B standard methods)
- BOD_5 using WTW BOD meter made in Germany, Model TS606 / 2-I (according to the 5210-D standard methods)
- Turbidity: Turbidity meter, HACH Company made in USA, Model 2100P (2130 standard methods)
- TDS: Gravimetric method at 180° (according to the C_2540 standard method)

Nitrate and Total Phosphate were also read using a DR-5000 spectrophotometer at 220 and 680 nm spectra respectively. (according to the 4500-NO_3-B and 4500-P-E Standard method). The fecal coliform samples were also counted using 9-tube MPN fermentation method (according to the 9221-B Standard method)

The number of tests conducted was equal to 225 based on the number of months of sampling, the number of sampling stations and the number of quality parameters measured. To analyze the data, the tests including ANOVA, Tukey and Kruskal-Wallis were used using Excel and statistical SPSS software, version 23. ANOVA and Tukey test was used To determine the presence or absence of difference between the average parameters (Based on the station and months of study). For this purpose, the Kruskal-Wallis test was used for Data with non-normal distribution.

Calculating the index

According to Equation, the NSFWQI index is calculated from summing the product of two factors, including weight and quality parameter. In this study, for accurate calculation of the NSFWQI index, the Online NSFWQI Calculator software of the Engineering Environment and Earth Sciences Department, Center for Environmental Quality, Wilkes University was used (Ghorbani *et al.*, 2014 ; Behmanesh *et al.*, 2013). Wilkes University has provided the internet NSFWQI software to calculate the Water Quality Index of the American National Health. Using this program, the quality index of each parameter and the Total Quality Index can be calculated in a shorter time (Oram,2005).

Equation for calculating the final index:

$$\mathbf{NSFWQI = \Sigma\ Wi\ Qi}$$

NSFWQI = Water Quality Index, which value varies from zero to 100

Wi = Weight or degree of priority of the factor (from zero to one)

Qi = Index Quality (from zero to 100)

Results

As Figure 2 shows, the NSFWQI Index changes of the river water quality were different at different stations, and the fluctuations in the quality index vary between 37 and 80 (figure 2). According to Figure 2, the highest index value equal to 80 in February was related to the third station, while the lowest value, 37 in June was seen in the fifth station. Based on the mean of the mentioned index (Figure 3 and Table 4), the river water quality was Medium in stations 1, 2 and 4, while the quality was good at station 3 and bad in the last station. The mean and standard error of the assessed parameters are listed in Table 3.

The results of statistical tests showed that temperature and pH parameters presented no significant differences comparing the different stations. However, significant differences were seen between different stations for the other measured parameters ($P< 0.05$). According to measurements taken during 5 months of sampling, the following results were found:

- The highest nitrate concentration: At Hameh Kasi station in June as 37.7 mg/l
- Total phosphate: At Latgah station in March as 6.41 mg/l
- Total dissolved solids: At Hameh Kasi station in June as 760 mg/l
- BOD_5: At the fifth station (Latgah) in May as 46 mg/l
- The lowest concentration of dissolved oxygen: At Hameh Kasi station in April as 4 mg/l.

Table 2: Water Quality Index manual (Shokuhi *et al.*, 2012)

INDEX VALUE	STATUS	COLOR	CLASSIFICATION OF TYPE OF USING WATER SOURCE
90-100	Very good	Blue	Having a normal status; if used for drinking water supply, it would not need to be refined; suitable for fisheries and aquatic sensitive species
70-90	Good	Green	In case of use for drinking water supply, it needs conventional treatment; suitable for recreational purposes such as swimming
50-70	Medium	Yellow	To be used for drinking water supply, it needs advanced treatment; suitable as drinking water for domestic animals
25-50	Bad	Orange	Fit for irrigating agricultural lands
0-25	Very bad	Red	Suitable for none of the above uses and is only able to support a limited number of aquatic forms

Table 3: Average and Standard Error values of water quality variables

PARAMETER	UNIT	STATIONS				
		S1	S2	S3	S4	S5
pH	-	7.44±0.04	7.45±0.04	7.61±0.09	7.47±0.06	7.42±0.08
Temp	˚C	9.40±1.43	10±1.41	10.6±1.50	11.4±0.92	13±1.09
DO	mg/l	7.26±1.26	8.38±0.82	9.32±0.53	8.16±0.91	5.10±0.14
BOD_5	mg/l	5.40±2.27	2.60±0.67	1±0	2.2±0.73	29.8±7.65
TDS	mg/l	516.20±65	368.4±28.68	452.6±20.51	639.6±34.31	504±51.60
Turbidity	NTU	6.70±2.13	2.65±2.14	0.43±0.21	0.5±0.32	19.06±2.97
Phosphate	mg/l	0. 3±0.08	0.08±0.03	0.05±0.01	0.04±0	4.86±0.65
Nitrate	mg/l	29.03±3.83	5.50±0.13	6.47±0.99	21.58±1.08	9.31±0.81
FC	N/100ml	225±73.95	679±257.94	753±223.67	24±4.89	897±202.5

Table 4: Results of NSFWQI index; mean of each station parameters

PARAMETER	UNIT	S1	S2	S3	S4	S5
Temp	˚C	48	45	42	45	34
pH	-	93	93	92	93	93
TDS	mg/l	20	51	40	20	20
Turbidity	NTU	83	91	98	98	62
DO	mg/l	62	85	89	80	48
BOD_5	mg/l	54	69	95	76	5
NO_3	mg/l	28	63	59	35	53
PO_4	mg/l	81	97	98	98	14
FC	N/100ml	36	26	25	61	23
NSFWQI	-	56	68	72	69	39
Quality	-	Medium	Medium	Good	Medium	Bad

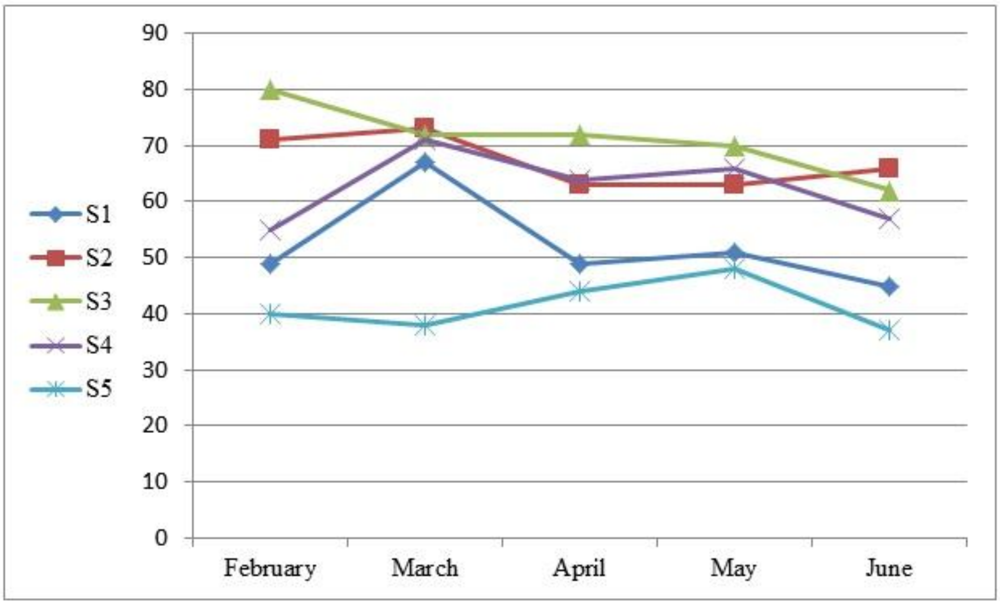

Figure 2: NSFWQI Quality index changes

In general, the quality index of stations had a decreasing trend, which occurred due to rising temperatures and reduced river discharge. The maximum value of index was equal to 80 in February related to the third station, while its minimum value was equal to 38 in June related to the fifth station. The index calculated for the mean of parameters in each station, showed that the first station (Hameh Kasi), the second station (Saleh Abad) and the fourth station (Qareh aghaj) were in a Medium quality class,with values of 56, 68 and 69 respectively, while the third station (Bahadorbeig) with an index value of 71 and the fifth station (Latgah) with an index value of 39 lied to good and bad quality class, respectively. Most of the studied rivers are in the quality class so that a small range in the third station of the river had a good water quality. Figure 3 shows the qualitative zones of studied rivers with green, yellow and orange colors.

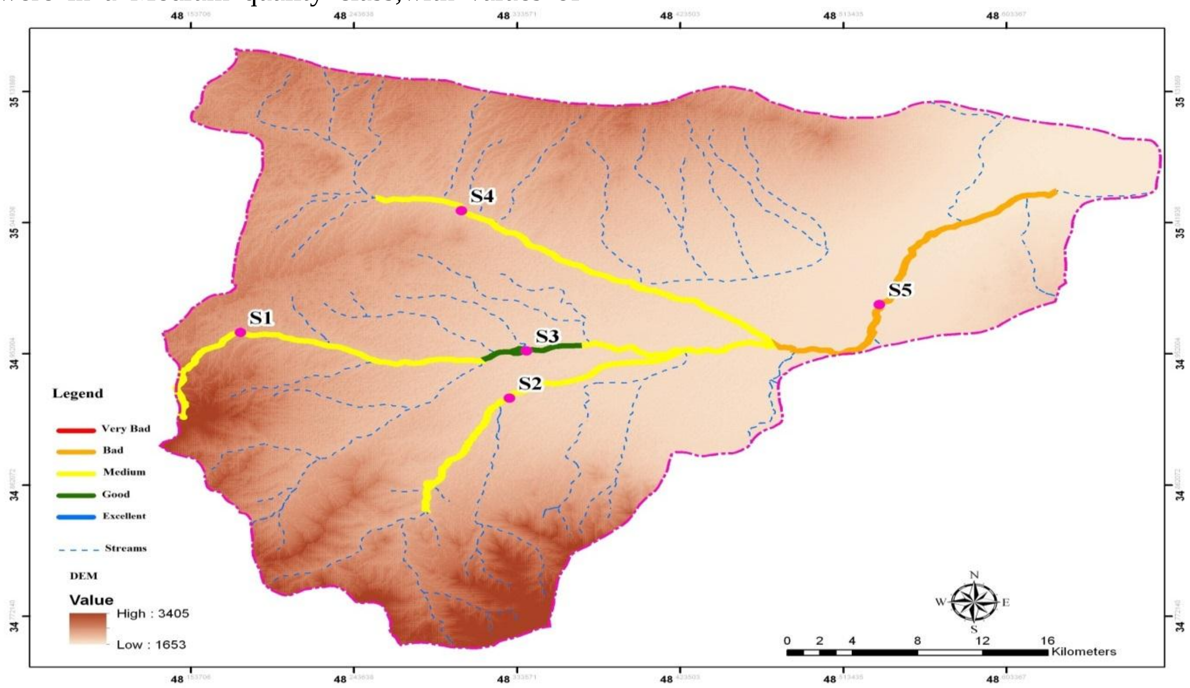

Figure 3: Qualitative zoning of the region Rivers based on the quality index of NSFWQI

Results and Discussion

Given the location of the first station (S1) near the Hameh Kasi River headstream and gorge, the river water quality was expected to be higher in the area than other stations. In contrast to our results, many studies have evaluated the water quality as good in upstream and primary stations. Due to proximity of the station to the village and direct discharge of some houses sewage into the river and agricultural lands developed along the banks of the river as well as the land sloping towards the river, the quality of this station is somewhat less than the next stations . It has been reported, through the evaluation of jarahi river water quality, that in general, the agricultural lands closer to the surface waters would have higher water pollution (Zohrabi *et al.*, 2014). The most effective factors in lowering water quality in this station were the high levels of nitrate and somewhat the high BOD_5 levels. The quality index calculated for the mean of data in Saleh Abad station indicates the Medium close to good quality in the station. However, the presence of fecal coliforms in the water of the station suggested the entry of human sewage into the river water. This station had a good water quality in winter, but in the warm months, fell in the Medium quality class mainly due to the increase in fecal coliform levels and increased turbidity. The main factor of reduced quality in the station was sewage discharge of villages in the upstream of the station.

In assessing the water quality of the Swan River in Himachal Pradesh, India, the river water quality was also assessed as medium to good levels (Sharda and Sharma, 2013). The water quality in the third station (Bahadorbeig) has occurred in a good quality class based on NSFWQI. In the third station, the steep bedrock has led to natural aeration of water and increased amount of dissolved oxygen. Since the amount of oxygen has a great importance in determining the quality index, thus, in the present study, the third station was in the good class; however, the high levels of fecal coliforms in the station indicated the entry of sewage into water. In addition, the river water passed a long distance from station 1 to station 3, and the water flow rate in this station showed a substantial increase compared to the first station. These factors have caused the water self-purification and increased its quality. The lowest amount of BOD_5 (at a rate of 1 mg/l) in this station (S3) among other stations confirmed the issue. The presence of abundant green plants in the station and water turbulence in the upstream has been effective in the increasing dissolved oxygen in water and consequently increased water quality of the station. Farzadkia *et al.*(2014) in their study on Ardabil Balekhlu River, the better quality of the third and fourth stations compared to the second station with the worst quality conditions reported due to the self-purification of the river and lack of pollution sources. Improved quality of the last station on the GolGol River in Mohseni's study has been mentioned due to self-purification of the river (Mohseni bandpey *et al.*, 2013) The index value of Bahadorbeig station (S3) in June was in the medium quality class, which was due to the reduction of flow rate as a result of an increase in BOD_5, decreased dissolved oxygen as well as increased depletion.

The river water quality in the fourth station (Qarahaghaj) is in the medium class. Low levels of fecal coliform in this station can be due to the entry of less human and animal waste into this station, since the station is located at the start of the branch stream. Aqiany *et al.* (2013) reported the agricultural waste as one of the factors polluting the Pasikhan River, which had significant effects on the river's water quality. The present study results also showed that the water quality at the fifth station was in the bad quality class based on the NSFWQI water quality index. In a study conducted by Dehghanzadeh *et al.* (2010) on the Mehran River in the city of Tabriz that this river is highly polluted with sewage and unsanitary, and the river water quality index varied in the range of 41-52, which indicated the river water quality included that in bad waters class. Given that the fifth station is located at the exit of all the waters of the watershed areas of Hamedan- Bahar and due to swage discharge of population centers in the path of input branches to this station, the water in this spot was in the bad quality class. Low water quality in the last station in this study is consistent with the results of many studies. Sanchez *et al.* (2007) studied the water quality index and dissolved oxygen deficiency along the Guadarrama and Manzanares rivers. The study results showed that the water quality index at the beginning of the Guadarrama River has a numerical value of 70 (good quality) and at the end of the river a value of 64 (medium quality).

In the present study Municipal and industrial wastewaters discharged in the path of input branches have accumulated in the fifth station (S5) provide the possibility of increased concentration of pollutants in the station. In addition, the wastewater of Hamedan treatment plant and the bypass of the treatment plant untreated wastewater also enter to this station. Yusefzadeh *et al.*(2013) have also considered the reduction of river water quality of Khorramabad River, Khorramabad, in the sixth station due to industrial wastewater discharge from the food industry around the river, bypass discharge of the untreated wastewater of Khorramabad urban treatment plant as well as the nearby farms effluents.

In Hamedan province, both surface water and groundwater sources are used for irrigation; however, in areas with access to the surface water, the use of surface waters is a priority in agricultural use in terms of ease of use, relatively low costs and no need for energy compared to the use of groundwater resources (Rahmani *et al.*, 2008). Due to the high area of agricultural lands planted around the river and water withdrawal for irrigation by pumping from the river as well as constructing canals for irrigation the farms, the agricultural drainage waters are considered as water pollutant factors, which enter into the river stream and significantly affect the physical, chemical and biological properties of the river.

According to the results, in general, one can say the entry of contaminated agricultural wastewaters, urban and rural homes swage discharge and Hamedan treatment plant effluent discharge are among the most important factors effective in the quality of surface waters in city of Bahar. To improve the quality of water resources in the area, the following factors and measures can be effective:

- Regular water quality monitoring and control of rivers water quality by the relevant organs
- Imposing restrictions and prohibitions on the river banks in conjunction with all activities and actions with the potential of contaminating the rivers
- Preventing the discharge of sewage into the aquatic environments beyond the self-purification capacity and potential of the river
- Creating a legal obligation for rural houses and home gardens in the agricultural lands for the pre- treatment of wastewater before discharge into the river
- Construction of sewage collection networks in urban and rural environments and a ban on sewage discharges into the aquatic environment without necessary treatment
- A total ban on the discharge of waste and construction and demolition wastes in the rivers banks and enforcement of legal regulations in this respect

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