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Original Article

Water Quality Evaluation of Torghabeh River of Mashhad Using Combination of NSFWQI Index and Geographic Information System

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ABSTRACT

Objective: Mashhad metropolis as the second largest religion city in the world and the second largest metropolis of Iran with an annual 3 million pilgrims have significant direct and indirect effects on the watershed leading to the city and surrounding over the past four decades. There is no collection system and sanitation disposal network in towns and villages within the Torghabeh River. **Methods:** Therefore, in this study the qualitative changes of Torghabeh River from October 2011 to September 2012 at 8 stations during four seasons (autumn, winter, spring, summer) was investigated by sampling of surface waters and measurement of water quality parameters along the river. Data from this study were analyzed using NSFWQI Index and finally was zoning using GIS software. **Results:** The results showed that the best and worst quality is related to stations 1 and 8, respectively. Moreover, it was found that the autumn season with an average of 46 has the best quality among the studied seasons. However, the worst situation (bad quality) was related to winter season with an average of 39. Finally, it can be concluded that the water quality of Torghabeh River in its different parts is far from the desired level.

1.INTRODUCTION

Surface waters in addition to their important role of providing bulk water needed for agriculture, industry and drinking, are the major arteries of the human, economic and social communities and are rooted in the lives of the people of each territory. Thus, having safe water supplies is an essential prerequisite for maintaining the quality of the expansion of science, civilization and human culture(Fabiano dos Santos,et al,2008) The growing human population and development activities, increased human access to environmental resources and the exploitation of renewable or non-renewable resources of land and has led to changes in water quality in rivers. In fact, population growth and pollution derived from the discharge of urban, industrial and agricultural wastewater, landfill leachate and also surface runoff has led to more contamination and limitation of water resources (Simeonov,et al,2003).Therefore, persistent monitoring of water quality is important. Nowadays, the use of water quality indicators is one of the methods which are very simple and away from complex statistical and mathematical. They can reflect the water quality conditions, use as a strong management tool for relevant decisions and applied to the analysis of river pollution(Liou,et al,2003)Water quality studies and zoning according to America National Sanitation Foundation Water Quality Index (NSFWQI) not only shows the quality of the river water, but it helps to the sustainable development and increasing the productivity of the river. The NSFWQI is one of the indicators which are complete, comprehensive and common for surface water quality classification. It can be determined based

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on selected parameters like DO, pH, turbidity, total solids (TS), temperature, BOD, phosphate, nitrate and fecal coliform (Herna´ndez- Romero,et al,2004). The index is calculated from the following equation:

$NSFWQI=W_i I_i$

As the I_i and W_i in this formula are equal to sub-index and weight coefficient of index, respectively. After identifying the water quality parameters of interest and their ranges of acceptability for the intended uses of the water body, compare the measured value with the subjective rating curve and arriving at a dimensionless sub-index value (0–1) for each parameter. Then, it is multiplied by a "weighting factor," based on that test's importance in water quality. The nine resulting values are then added to arrive at an overall water quality index (WQI).(Samadi,2009) NSFWQI index is a reduction index namely it is decreases with increasing of water pollution. This index has a value between 0 to 100 and is classified according to Table 1.(Banjaka D., et al., 2012).

Table 1: Water quality classification according to NSFWQI

Water quality	Index
Excellent	91-100
Good	71-90
Medium	51-70
Unsuitable (Bad)	26-50
Very unsuitable (Very Bad)	0-25

A qualitative assessment of Maroon River in three stations in the upper, middle and lower parts of river has been carried out using NSFWQI index (Jafarabadi, et al., 2010). The results indicate a decrease in the index value from the upstream to the downstream side of the river. In addition, the quality of water in the three stations were located in the middle class, so is suitable for drinking, but needs to be further refined. Also, other researchers took advantages of this index for Zoning of Zohreh River. The samples were collected monthly and during a water year from nine selected stations along the river. The results of this study showed that the water quality of river has been reached to inappropriate status from its proper position in the source which could be due to various effluent discharges along the river (karimian, et al,2006) Mirzaei et al also conducted a similar study on quantitative zonation of Jajrood River by NSFWQI during the year and seasonally. They concluded that despite the pollution entering on upstream of river; it has high natural purification power.

According to previous studies, Mirmoshtaghi in 2011, studied the water quality of Sefidrood River by investigation of 20 samples at 5 sampling stations according to NSFWQI index and compared the results with OWQI index. The results showed that maximum and minimum values of NSF were 57 and 32, respectively. And the average value of NSFWQI along with Sefidrood River was obtained equals to 47.5, which is placed at bad region. Also, calculation of OWQI index showed the very bad quality of Sefidrood River during the study period (Mirmoshtaghi, 2012). Karami et al (2009) evaluated and optimized the relationship between NSFWQI and physical, chemical and biological parameters of Bamdezh Wetland. Karami et al (2010) in an another project introduced a conceptual model for determination of environmental water requirement for Bamdezh Wetland.

Various studies show that the zonation of river water quality is the first and most important step for surface water quality management. On the other hand, zoning of pollution and providing the accurate picture of the status of surface water quality by GIS software makes any management decisions that their environmental impacts directly or indirectly affect the surface water, to be taken with more knowledge(Houshmand,2008).Therefore, determination of water quality of Torghabeh River based on NSFWQI index, monitoring the amount of contamination in the river and also the comparison of water quality in defined stations during the river path are the aims of this study.

2. MATERIALS AND METHODS

2.1. Site Specification

The study region with an area of 313 Km^2 is located on watershed of Torghabeh River. It lies at a distance of 5 km in the South West of Mashhad between the north latitude 36° 8‘"50 to 36° 19‘ 45" and the east longitude 59° 10‘18" to 59° 29‘ 20". Dehbar branches with 118 Km^2 is allocated to the greatest extent while Mayan and Jagharq outlets are collecting stream catchment area of 113 and 71 Km^2, respectively. The Hesar branches surface watershed encompasses only 11 Km^2 which Dehbar basin is also relevant to this river. The sea level altitude of Mayan, Dehbar and Jagharg is 2804, 2960 and 3090 m, respectively.

2.2. Data Collection

The eight stations along Torghabeh River has selected based on its length in order to monitor the water quality of River. As, three points were elected from subsidiary branches that supply the river. Another four stations were chosen along the main branch of the river and one more point was selected at the intersection of selected tributaries and main branches of river (Figure 1). Geographic coordinates of the stations was determined using GPS Gardin Device (Model e Trex VISTA).(Table

2).The sampling was carried out in the eight stations and four seasons (from October 2011 to September 2012). In this study, the sampling was repeated five times in each station in order to decline the error of measurement**.**

Table2:

Station's Number	Station's Name	Station's geographical coordinates	The sea level altitude (m)
1	Before Jagharq Village	"32.53'18°36N"13.20'19°59 E	1420
2	After Jagharq Village	"37.62'18°36N"38.84'20°59 E	1367
3	Before Torghabeh City	"32.49'18°36N"45.08'21°59 E	1323
4	After Torghabeh City	"38.06'18°36N"6.06'23°59 E	1268
5	Before Dehbar Village	"3.16'18°36N"5.61'23°59 E	1231
6	After Dehbar Village	"28.56'17°36N"31.00'23°59 E	1219
7	Mayan Village	"45.39'17°36N"19.87'24°59 E	1329
8	Before Golestan Dam	"2.95'19°36N"42.78'24°59 E	1211

Station's geographical coordinates

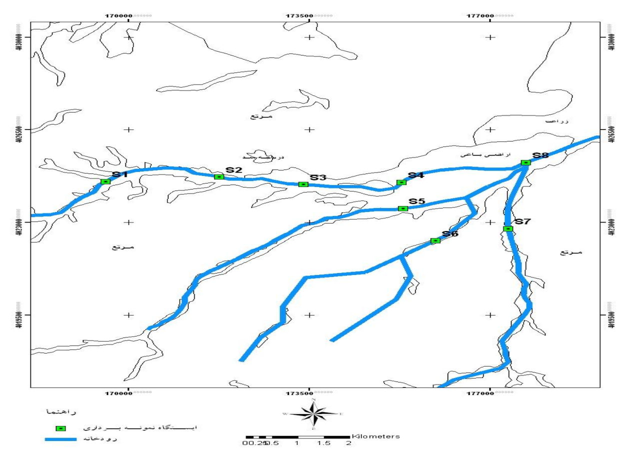


Figure 1: Torghabeh River and its sampling station position

2.3. Data analysis

2.3.1. NSFWQI Calculation

In this research, some physicochemical and bacteriological data were analyzed to evaluate the water quality and quality zoning of the Torghabeh River. These data consist of 9 parameters based on NSFWQI method which are DO, pH, BOD, Temperature, Turbidity, TS, Nitrate (NO_3), Phosphate (PO_4) and Fecal coliforms (FC). All samples were analyzed in accordance with APHA methods (APHA 2005). Weighting averages of parameters required for NSFWQI should be calculated, and then sub-index of each parameter must be determined based on specific charts. Finally, NSFWQI of each sampling point determined by multiplying sub-index to weighting average of each parameter. The Calculating NSFWQI Water Quality Index software which was used for sub-index and NSFWQI determination of this study is available in Wilkes University webpage(Center for Environmental Quality Environmental Engineering and Earth Sciences). Preparation of water quality zoning maps (Spatial distribution of water quality) using GISInterpolation method was used to characterize the changes of water quality index along the river. This method can estimate the unknown values of certain points using known amounts of measured pure samples. Semi-variance of variables was calculated before zoning in order to select the best method of interpolation and the semi-variogram curve of parameters was then prepared. It was found that the Inverse Distance Weight (IDW) was more appropriate interpolation method as compared to Kriging one according to the graphs and number of samples (8 samples). Finally, the zoning maps of the river which shows spatial distributions of the water quality index was prepared using ArcGIS.

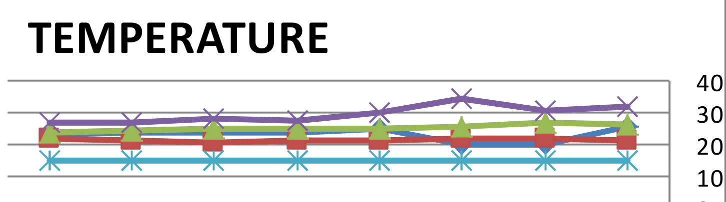
3. RESULTS AND DISCUSSION

Results were analyzed as follows after measuring water quality parameters of Torghabeh River and curve *drawing.*

3.1. Qualitative changes of the studied parameters in different stations and seasons

3.1.1. Temperature

The lowest measured temperature was related to winter at the Station 3 which is a function of ambient temperature conditions. The temperature at all stations and seasons is higher than drinking water standards. Moreover, the water temperature has increased from upstream to downstream of the river (Figure 2). This might be due to the increasing of biological activity and organic matter decomposition which resulted into the BOD increment and DO reduction.

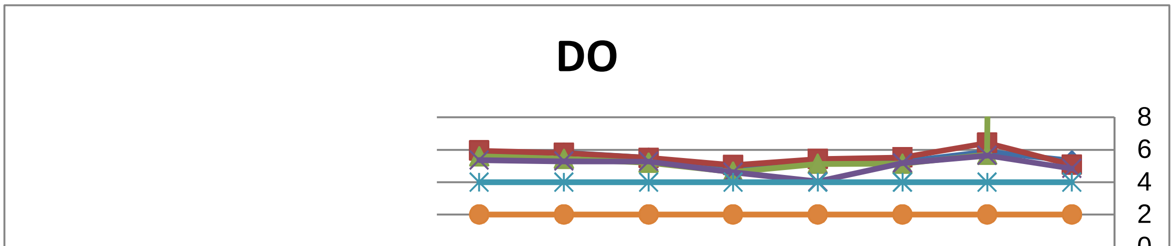


	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	23.56	24.08	24.18	24.08	25	19.92	20	25.6
Winter	21.76	21.58	20.98	21.36	21.32	21.82	21.76	21.6
Spring	24.16	24.84	25	24.92	25.34	25.98	26.78	26.6
Summer	27.08	27.04	28.52	27.4	30.2	34.32	30.86	31.8
Drinking water standards based on WHO and department of energy	15	15	15	15	15	15	15	15

Figure 2 : Average water temperature in different stations and seasons

3.1.2. DO

As can be seen in Figure 3, the DO levels measured at all sampling points in all seasons of the Torghabeh River was higher than the minimum of drinking water standards. The DO measured in different seasons is varied between 4.61 and 5.94. The minimum amount of DO required for survival of fish and freshwater species is determined at 6.5 mg/L according to United States Environmental Protection Agency (USEPA) standards. It is 9.5 mg/L for spawning stage of aquatic species. However, the DO of Torghabeh River is out of this range. Besides, it has been found that this river is suitable for irrigation purpose (Figure 3).

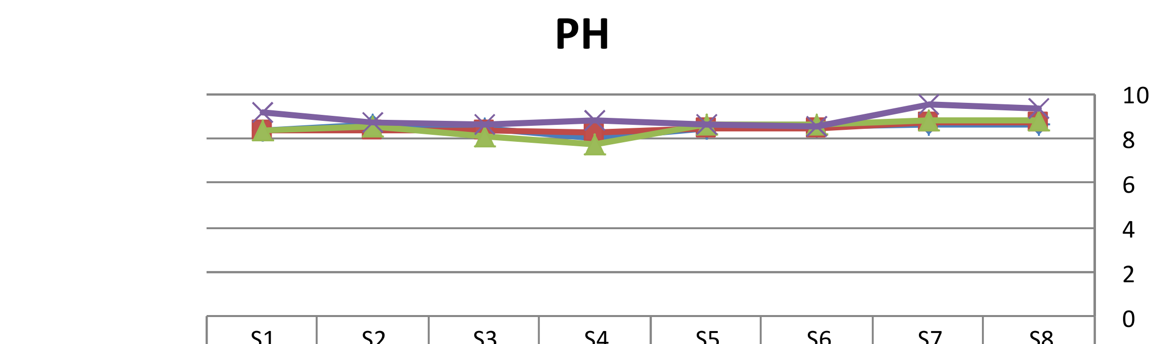


	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	5.82	5.82	5.5	4.74	5.21	5.27	5.88	5.32
Winter	5.94	5.81	5.5	5.05	5.43	5.53	6.42	5.07
Spring	5.6	5.44	5.2	4.64	5.13	5.14	5.7	511
Summer	5.36	5.29	5.27	4.61	4.03	5.18	5.65	4.84
Drinking water standards based on WHO	4	4	4	4	4	4	4	4
Iranian irrigation standards	2	2	2	2	2	2	2	2

Figure 3 : DO average in different stations and seasons

3.1.3. *pH*

Generally, the fall season had the lowest intake of alkali or carbonate, but in the summer we recorded the highest value possible. This might be due to the reduction of tourism and usage of fertilizers and chemical pesticides during autumn. Moreover, it has been found that the water acidity has extremely increased from upstream to downstream of the river. The water at all stations and seasons is located within the drinking water standards except summer. As the stations of 1, 7 and 8 are out of drinking range during hot season. The station 4 during autumn and spring seasons is only found suitable for irrigation usage while the other seasons and stations are not acceptable from irrigation standpoint (Figure 4).



	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	8.33	8.61	8.48	8	8.45	8.53	8.6	8.58
Winter	8.39	8.38	8.37	8.22	8.46	8.48	8.73	8.72
Spring	8.39	8.57	8.08	7.76	8.65	8.61	8.82	8.83
Summer	9.13	8.68	8.66	8.8	8.63	8.54	9.52	9.35

Iranian irrigation standards= 6/5-8/4

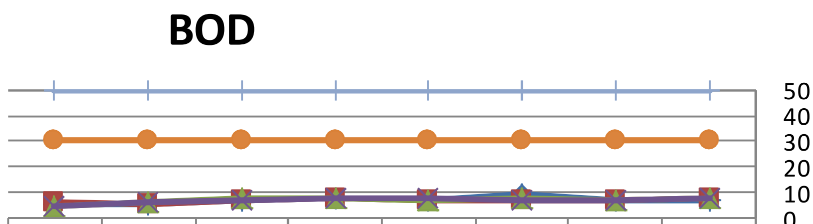
Drinking water standards based on WHO= 6/5-9

Drinking water standards based on department of energy= 6/5-9/5

Figure 4 : pH average in different stations and seasons

3.1.4. BOD

According to Figure 5, it has been found that the lowest and highest amount of BOD is related to Station 1 at spring and Station 6 at autumn, respectively. Generally, the BOD level of all seasons has increased from upstream to downstream of the river. The BOD of all sampling points is found suitable for agriculture and irrigation usage based on irrigation standards. Moreover, the stations of 1 and 2 are only acceptable for irrigation usage as the appropriate amount of BOD required for survival of fish and freshwater species is determined at 3-6 mg/L according to USEPA standards.

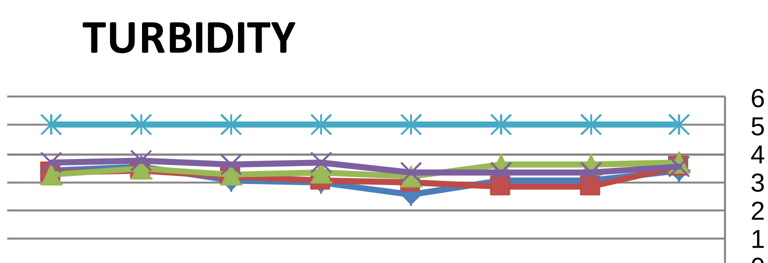


	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	5.67	5.5	7.13	7.94	7.38	9.39	6.82	7.35
Winter	5.95	5.22	7.35	7.84	6.89	6.71	6.8	7.75
Spring	4.92	5.98	7.94	8.09	7.16	7.53	6.8	8
Summer	5.09	5.91	7.23	8.16	7.53	7.43	7.18	7.87
Iranian irrigation standards	100	100	100	100	100	100	100	100
Drinking water standards based on WHO	30	30	30	30	30	30	30	30
Drinking water standards based on department of energy	50	50	50	50	50	50	50	50

Figure 5 : BOD average in different stations and seasons

3.1.5. Turbidity

As can be seen in Figure 6, the amount of turbidity has increased from autumn to summer and also upstream to the downstream side of river which could be due to the solids entering increment to the river. The lowest and highest amount of turbidity at the studied seasons is related to Station 5 at autumn and Station 8 at summer, respectively. Turbidity levels in autumn and at stations 1 and 2 were high while it was dropped from Station 3 to 6. However, at Stations of 7 and 8 shows the rise trend again.



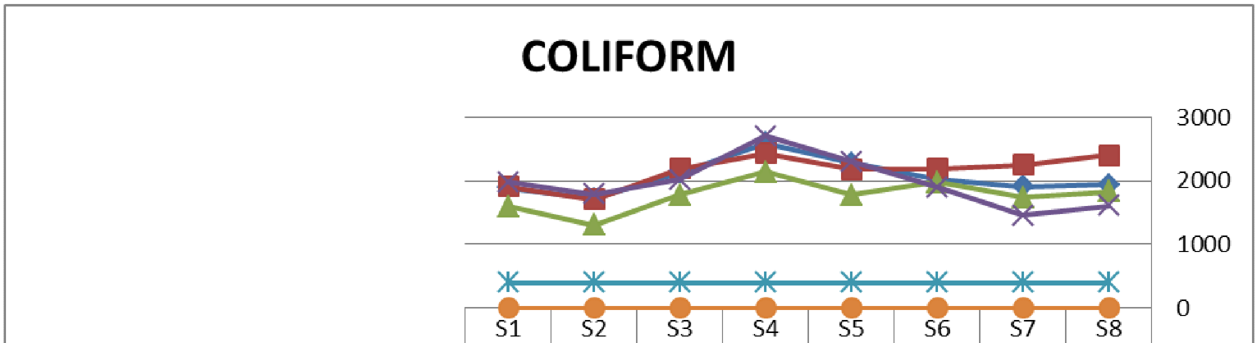
	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	3.38	3.52	3.02	2.99	2.57	3.05	3.05	3.36
Winter	3.35	3.39	3.17	3.07	2.99	2.79	2.79	3.55
Spring	3.28	3.48	3.25	3.34	3.19	3.61	3.61	3.69
Summer	3.67	3.78	3.6	3.68	3.33	3.35	3.33	3.53
Drinking water standards based on WHO	5	5	5	5	5	5	5	5

Drinking water standards based on department of energy= 5-25

Figure 6 : Turbidity average in different stations and seasons

3.1.6. Fecal coliform

The lowest and highest amount of measured coliform is related to winter and spring, respectively. It represents the microbial contamination increment at winter as a result of more rainfall and agricultural and urban runoff into the river (Figure 7).



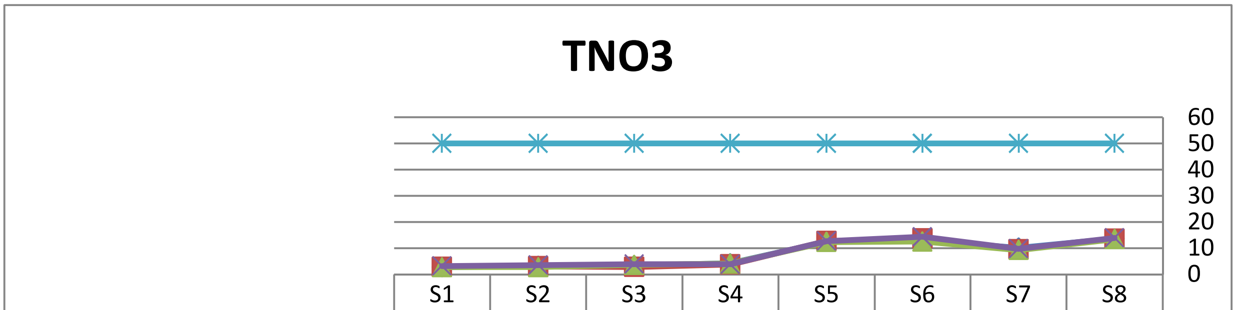
	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	1893	1720	2133	2599	2284	2034	1911	1942
Winter	1907	1707	2190	2436	2186	2190	2257	2407
Spring	1597	1310	1775	2144	1782	1979	1738	1834
Summer	1982	1788	2026	2706	2308	1905	1461	1606
Iranian irrigation standards	400	400	400	400	400	400	400	400
Drinking water standards based on WHO	1	1	1	1	1	1	1	1

Figure 7 : Fecal coliform average in different stations and seasons

3.1.7. Nitrate

According to Figure 8, it could be said that the amount of nitrate anion and its variation trend in this study was quite significant and has the most important effect on water quality.

There is no any NO_3 pollution in the Torghabeh River and therefore it is located within the drinking water standards at all seasons. The result of this study shows the highest amount of NO_3 at Station 6 in summer and its lowest concentration at Station 1 in autumn. The NO_3 of the Torghabeh River is found suitable for agriculture and irrigation usage based on irrigation standards.



	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	2.7	3.27	3.44	4.21	12.46	13.07	10.17	13.65
Winter	2.88	3.07	2.82	3.8	12.7	13.75	9.59	13.55
Spring	2.73	2.75	3.61	4.11	12.33	12.55	9.3	13.42
Summer	3.16	3.52	3.93	3.86	12.73	14.37	9.78	13.96
Drinking water standards based on WHO	50	50	50	50	50	50	50	50

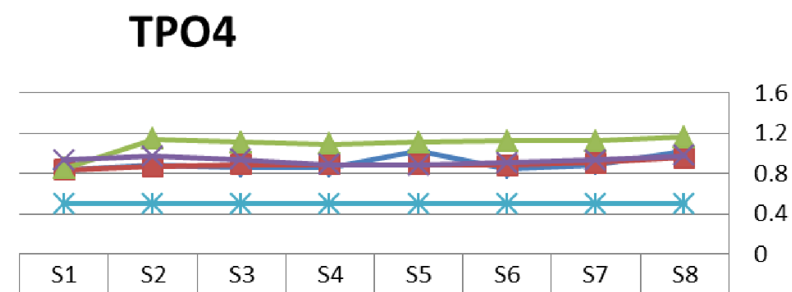
Iranian irrigation standards= 5-30

Drinking water standards based on department of energy= 5-50

Figure 8 : Total nitrate (TNO_3) average in different stations and seasons

3.1.8. Phosphate

The phosphate concentration is the second important parameter influencing the water quality of Torghabeh River. The lowest amount of phosphate was detected at Station 1 in autumn and winter while its highest concentration was related to Station 8 during spring. This might be due to the great amount of detergent entrance to the river as well as high quantity of pesticide usage for agriculture purpose during spring. In general, the amount of phosphate has increased from upstream to the downstream side of river. However, the studied river is not located in the suitable range of drinking water standards (Figure 9).



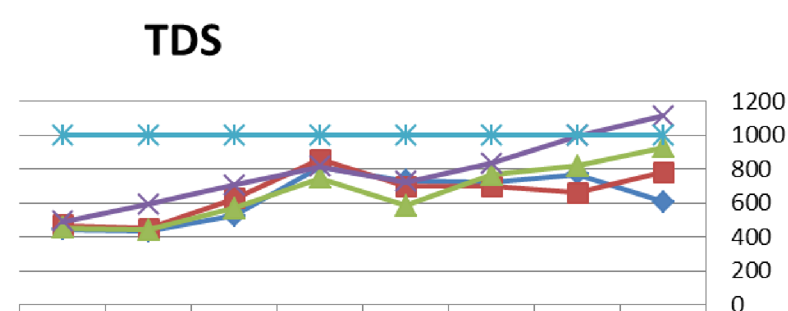
	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	0.84	0.88	0.86	0.86	1.02	0.85	0.89	1.02
Winter	0.84	0.87	0.89	0.89	0.89	0.88	0.91	0.96
Spring	0.85	1.14	1.11	1.09	1.11	1.12	1.12	1.16
Summer	0.93	0.97	0.94	0.89	0.88	0.91	0.93	0.98
Drinking water standards based on WHO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Drinking water standards based on department of energy= 0/1-0/2

Figure 9: Total phosphate (TPO_4) average in different stations and seasons

3.1.9. TDS

As can be seen in Figure 10, the TDS levels measured at all stations and seasons of the Torghabeh River are within the drinking water standards according to Department of Energy. The station 8 during summer is only found not suitable for drinking usage while the other seasons and stations are acceptable based on WHO standards. Moreover, it has been found that the Torghabeh River is appropriate from irrigation standpoint. There is an increment trend on this parameter from upstream to downstream side of river.



	S1	S2	S3	S4	S5	S6	S7	S8
Autumn	446.96	434.54	525.6	813.5	732.86	719.9	770.64	608.78
Winter	469.2	448	625	854.9	697.86	697.33	658.76	779
Spring	454.39	442.2	568.8	748.1	583.46	766.95	818.16	926.54
Summer	490	590.61	706.2	816.46	723.06	834.54	997.12	1111.27
Drinking water standards based on WHO	1000	1000	1000	1000	1000	1000	1000	1000

Iranian irrigation standards= 200-2000

Drinking water standards based on department of energy= 500-2000

Figure 10: Total TDS average in different stations and seasons

3.2. Water quality evaluation of Torghabeh River using NSFWQI index in different stations and seasons

The result of this study shows that the water quality of studied river at Stations 1 and 2 from October 2011 to April 2012 was in medium class based on NSFWQI index while the other stations were locate in bad session. However, the aforementioned stations during winter shows the lower amount as compared to autumn which might be caused by winter rainfall and its effect on pollutant's dilution. Moreover, the pollution amount has increased from upstream to downstream side of river (Table 3). In fact, it could be derived from the direct discharge of urban, industrial and agricultural wastewater to the river, landfill leachate as a result of solid waste accumulation beside the river and also surface runoff. Moreover, it has been found that the all stations in summer are located in bad class which might be due to the tourism growth and high dose of pollutant entrance to the river during hot season (Table 2). In the study was carried out by Hooshmand et al. (2006) on Karoon River at 4 stations during 3 years, it was found that the water quality of river is classified as medium. Enrique et al. (2003) also reported the good and medium quality for upstream and downstream of Guadarrama River based on NSFWQI index while it was located in medium session for Manzares River.

Table 3 : Water quality of Torghabeh River presented by NSFWQI index in the studied stations and seasons

Water Quality	NSFWQI value	Station's Number	Station's Name	seasons
Medium	54	1	Before Jagharq Village	**Autumn**
Medium	52	2	After Jagharq Village	
Bad	49	3	Before Torghabeh City	
Bad	48	4	After Torghabeh City	
Bad	44	5	Dehbar River	
Bad	43	6	Hesar River	
Bad	44	7	Mayan River	
Bad	44	8	Before Golestan Dam	
Medium	51	1	Before Jagharq Village	**Winter**
Medium	50	2	After Jagharq Village	
Bad	48	3	Before Torghabeh City	
Bad	46	4	After Torghabeh City	
Bad	42	5	Dehbar River	
Bad	42	6	Hesar River	
Bad	44	7	Mayan River	
Bad	40	8	Before Golestan Dam	
Medium	54	1	Before Jagharq Village	**Spring**
Medium	50	2	After Jagharq Village	
Bad	48	3	Before Torghabeh City	
Bad	46	4	After Torghabeh City	

Bad	41	5	Dehbar River	
Bad	41	6	Hesar River	
Bad	43	7	Mayan River	
Bad	40	8	Before Golestan Dam	
Bad	49	1	Before Jagharq Village	**Summer**
Bad	49	2	After Jagharq Village	
Bad	48	3	Before Torghabeh City	
Bad	45	4	After Torghabeh City	
Bad	44	5	Dehbar River	
Bad	43	6	Hesar River	
Bad	41	7	Mayan River	
Bad	41	8	Before Golestan Dam	

Table 4 also shows the summary of NSFWQI index of some of the rivers as reported in the literature, in comparison with the present study. It is seen that the Torghabeh River has worst index as compared to the river of Karoon (including Zargan,Darkhin,Gatvand and Omolteir), Bamdezh Wetland and Maroon while it has the same quality as Ajichai River. On the other hand the Torghabeh River has best index as compared to the rivers of haraz, Babolrod, Siahrod.Moreover, the aforementioned river has a more difficult situation as compared to the river outside the country.

Table 4 : An overview of NSFWQI index of various rivers of the world

River's Name	NSFWQI Index	Reference
Torghabeh	44.5	This study
Karoon (including Zargan- Omolteir)	70	Safarian, et al,2007
Karoon (including Gatvand, Darkhin)	50-65	Houshman,et al,2008
Karoon (including Khuramshahr)	40-54	Dadelahi & Arjmand,2010
Ajichai	44.5	Fataei,et al,
Maroon	57	Gararabadi,et al,2010
Halali	61-80	Sharma et al. 1996
Cauver	50-70	Suvarna et al, 1997
Haraz	42	Norbakhsh,et al,2014
Babolrood	41	Norbakhsh,et al,2014
Siahrood	40	Norbakhsh,et al,2014
Bamdezh Wetland	62-69	Gorgizade,et al, 2014

Mahanadi	71	Samantray,et al, 2009
Atharbanki	53	Samantray,et al, 2009
Taladanda Canal	76	Samantray,et al, 2009

3.3. Water quality zoning maps (Spatial distribution of water quality)

ArcGIS software was used to this study in order to processing spatial distribution of water quality to enable comprehensive analysis on the results that are presented as maps. The output of this section is the zoning maps that show's spatial distributions of the water quality index at different seasons (Figures 11 -15).

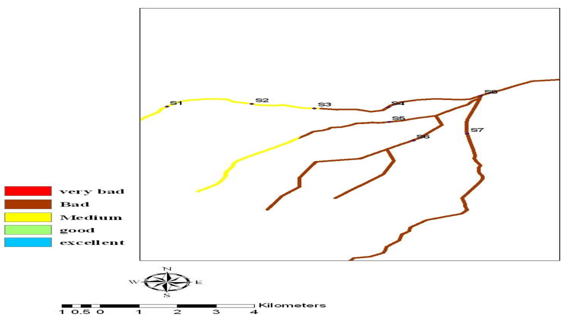


Figure 11 : Spatial distribution of NSFWQI in Torghabeh River at October 2011

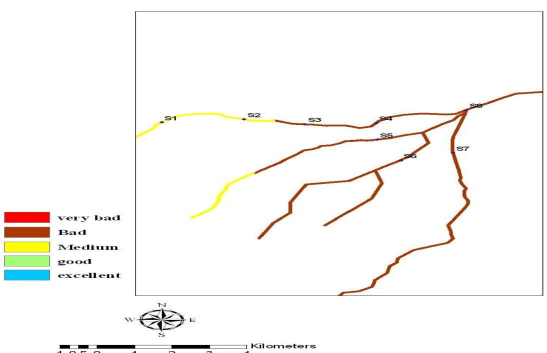


Figure 12 : Spatial distribution of NSFWQI in Torghabeh River at December 2011

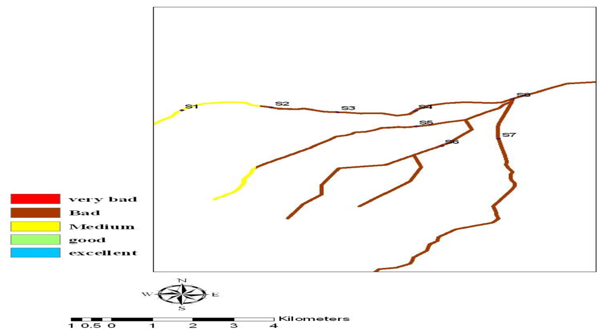


Figure 13 : Spatial distribution of NSFWQI in Torghabeh River at April 2011

Figure 14 : Spatial distribution of NSFWQI in Torghabeh River at September 2011

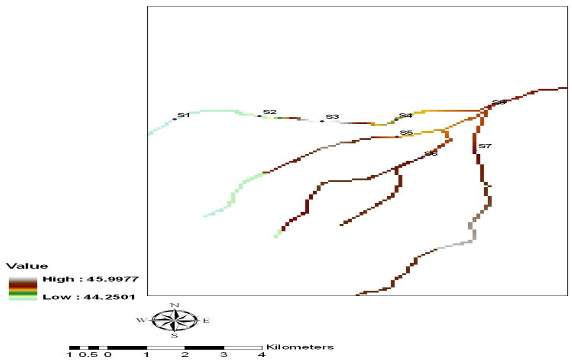


Figure 15 : Spatial distribution of NSFWQI in Torghabeh River at all studied seasons

CONCLUSION

Torghabeh River in the North East of the country covers the largest number of tourists, both local and non-local accounts. On the other hand, the existence of Torghabeh city, intense focus features, tourist facilities and new residential complexes in the route of one of the major branches of the Torghabe River, make it very important. The assessment of water quality using NSFWQI index shows that the best and worst class are related to the Station 1 and 8, respectively. Moreover, autumn season with average index of 46 has the best quality while winter with average amount of 39 has the worst one. It also has been found that the water quality of the studied river in most of the sampling point is out of optimal rate. As the Station 1 and 2 during autumn, winter and spring are in the bad and medium class, respectively. However, the other stations at all seasons show the bad quality. Therefore, more stringent rules need to adopt in order to protect the water source from contamination values, provide the community health and preserve this precious resource for future generations.

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