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Comparative Investigation of River Water Quality by OWQI, NSFWQI and Wilcox Indexes (Case study: the Talar River – IRAN)

Gholamreza Darvishi[1], Farshad Golbabaei Kootenaei[2]*, Maedeh Ramezani[3], Eissa Lotfi[4], Hosseinali Asgharnia[5]

[1]Babol Noshirvani University of Technology, Iran
Faculty of Civil & Environmental Engineering
[2]University of Tehran, Iran
Graduate Faculty of Environment, Department of Environmental Engineering
[3]Islamic Azad University, Iran
Young Researchers and Elite Club
[4]Regional Water Company of Mazandaran, Iran
[5]Babol University of Medical Sciences, Iran
Department of Environmental Health

*Corresponding author's e-mail: farshadgolbabaei@yahoo.com

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Abstract: Rivers are considered as one of the main resources of water supply for various applications such as agricultural, drinking and industrial purposes. Also, these resources are used as a place for discharge of sewages, industrial wastewater and agricultural drainage. Regarding the fact that each river has a certain capacity for acceptance of pollutants, nowadays qualitative and environmental investigations of these resources are proposed. In this study, qualitative investigation of the Talar river was done according to Oregon Water Quality Index (OWQI), National Sanitation Foundation Water Quality Index (NSFWQI) and Wilcox indicators during 2011–2012 years at upstream, midstream and downstream of the river in two periods of wet and dry seasons. According to the results of OWQI, all of the values at 3 stations and both periods are placed at very bad quality category and the water is not acceptable for drinking purposes. According to NSFWQI, the best condition was related to the upstream station at wet season period (58, medium quality) and the worst condition was related to the downstream in wet season period (46, very bad quality). Also the results of Wilcox showed that in both periods of wet season and dry season, the water quality is getting better from upstream station to the downstream station, and according to the index classification, the downstream water quality has shown good quality and it is suitable for agriculture.

Introduction

For proper application of water resources, communities, agricultural and industrial centers are usually constructed next to the rivers (Srinivas et al. 2013, Shamsai et al. 2006). Because of the increase of population, industrial development, increase of water salinity, pouring various organic and mineral pollutants into rivers as sewage and etc. Rivers are water bodies most vulnerable to pollution due to their role in transporting point and non-point discharges in their vast drainage basins (Boyacioglu 2014) and rivers are being contaminated and this contamination of water resources in most of the rivers around the world leads to serious threats to environment, agricultural products and human health (Jafarabadi 2012, Godghate et al. 2013). In many countries such as Iran, social and industrial developments changed the qualitative characteristics of the river water and leads to excessive pollution. Therefore, overall national planning and resource management in respect to water with emphasis on allocation of priorities among the different uses is necessary. It is not surprising that, due to the above factors, studying water quality is so much important to be carried out in order to keep our awareness and understanding of our environment (Abdul Hameed et al. 2010). Regarding apparent difference between limitation of water resources and daily increasing demand for these resources at communities, the emphasis is placed on continuous monitoring, control and treatment of surface waters. Therefore, continuous measurement and analysis of qualitative parameters of rivers are considered as the main issue for identification of water quality. While until now, limited studies of a few rivers have been done in Iran, nowadays in many developed countries, qualitative zoning of rivers have became a basic method for proper management of water resources (Cheraghi et al. 2007, Rahimi 2003). As a result, qualitative studies and zoning of rivers according to indicators of water quality standard, not only clear the qualitative conditions of the river water, it also leads to sustainable development and help to increase the productivity of the river (Mirmoshtaghi 2012, Bharti et al. 2011). By identifying those sections of the river where the water quality parameters are lower than the standard values, finding proper solutions for removing of these pollutants will become easier (Nazari et al. 2005, Eneji et al. 2012). Among the various indexes which are applicable for water quality zoning, NSFWQI was selected because of high precision, simplicity and availability of the required parameters (Shamsai et al. 2006, Zandbergen et al. 1988), and also OWQI index was selected and used because of being strict and having no weighting parameters which are involved in the index.

In 2011, Mirmoshtaghi studied the water quality of the Sefidrood River by investigating 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 for Sefidrood River equals to 47.5, which classifies it as a bad region. Also, calculation of OWQI index showed the very bad quality of the Sefidrood River water during the study period (Mirmoshtaghi 2012). Shamsai in 2006 studied 3 quality indicators of OWQI, NSFWQI and BCWQI for qualitative zoning of the Karoon River and the Dez River during 3 years. The results obtained from comparing these indexes showed that NSFWQI is preferred because of direct involvement of measured parameters on structure of sub-index and total-index and also by considering the weight effect on sensitivity (Shamsai et al. 2006). A similar study was conducted by Curtis in 2001. He studied the OWQI calculation method and type of sampling from the Oregon River, by investigating parameters such as pH, total solids, fecal coliform, phosphate, dissolved oxygen, BOD_5, nitrate and temperature. The results of that study showed that the OWQI index is a good indicator for zoning of the river. In another study, Cude showed the usefulness of the Oregon water quality index as a tool for water quality management. The Oregon water quality index is a single value which is representative of the water quality and obtained by combining the values of the eight above mentioned water quality variables (Cude 2001).

In this study, the water quality index (WQI) was represented by three indexes of NSFWQI, OWQI and Wilcox to evaluate the spatial and temporal changes of surface water quality in the Talar River, the scores calculated were used for classifying the water quality and assessing the impacts of industrial and rapid urbanization on the overall water quality of the river.

Material and Methods

To determine the structure of surface waters quality indexes, the data prepared by measurement of water quality parameters are considered as base of the progress. Although, depending upon the kind of the index and its objectives, the parameters are different. These parameters are representative of the chemical, physical and biological characteristics of the water. The functions and relations that build the mathematical structure of the indexes affect these parameters and finally present the index as a single number (Liu et al. 2012).

National Sanitation Foundation Water Quality Index (NSFWQI)

NSFWQI is one of the most widely used indicators which comprises nine main parameters such as pH, total solids, fecal coliform, total phosphate, dissolved oxygen, BOD_5, nitrate, turbidity and temperature. NSFWQI is obtained as below:

$$NSFWQI = \sum W_i I_i \tag{1}$$

In this equation, Ii is the quality of the ith parameter (a number between 0 and 100 read from the appropriate sub-index graph) and Wi is the weight factor of the ith parameter (Badalians Gholikandi et al. 2012).

After measuring the above characteristics, the sub-index of each of them is obtained from conversion curves. These curves convert the parameters into measures that range from zero to 100. To calculate the final index in this method, each sub-index obtained from the related curves is multiplied by weight factor, and the final index is obtained by the sum of them, according to Equation 1 (Ebrahimpur et al. 2012). For the calculation of NSFWQI and determination of Qi, the Wilcox Standard Graphs are used (Shamsai et al. 2006, Fabiano et al. 2008, Sanchez 2007). Classification of river pollution intensity and water description according to NSFWQI are presented in Table 1.

Oregon Water Quality Index (OWQI)

Generally, this index is used to assess water quality for recreational purposes. Simplicity, availability of required quality parameters, and the determination of sub-indexes by curve or analytical relations are some advantages of this approach. In this method, each of the eight parameters (as mentioned before) is no-weighting factor and has same effect on the final factor. Table 2 presents a water description according to the index numerical values. The final Oregon index is calculated by Equation 2; in this formula, n is the number of parameters

Table 1. Classification of river pollution intensity according to NSFWQI index

Calculated index	Class	Water Quality Condition
91–100	A	Excellent
71–90	B	Good
51–70	C	Medium
26–50	D	Bad
0–25	E	Very Bad

(n=8) and SI_i is the value of parameter i (Ebrahimpur et al. 2012). This index is calculated by Equation 2:

$$OWQI = \frac{n}{\sqrt{\sum_{i=1}^{n} \frac{1}{SI_i^2}}} \quad (6)$$

The standard graphs are used to calculate the SI_i (Shamsai et al. 2006). Finally, the pollution and water quality of the river is assessed according to Table 3.

Wilcox indicator

Nowadays, this index is considered as a very common method for classifications of water for agricultural purposes. In this classification, two factors, Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) are considered and each of them is divided into four sections which finally lead to the creation of totally 16 groups. The groups are classified as follows:

(1) Very good water with EC less than 250 µmohs/cm, it is in class C_1S_1.
(2) Good water that is related to one of C_2S_1 or C_2S_2 groups.
(3) Medium water that is related to one of C_3S_3, C_3S_2, C_3S_1, C_2S_3, C_1S_3 groups and is suitable for irrigation of lands with good drainage.
(4) Unsuitable water for irrigation that is related to one of C_4S_3, C_4S_2, C_1S_4, C_2S_4, C_3S_4, C_4S_4, C_4S_4 groups (Saghi 2011), and as the index is greater the quality is lower (Rahmani 2008). Tables 3 and 4 show classification of water for agricultural purposes.

Locations of sampling stations

Location Map of the Talar River in Mazandaran province is shown in Fig. 1. For the determination of sampling stations along the river pathway, some issues including the discharge place of municipal and industrial wastewater, agricultural drainage and other sources of pollutants into the river, the qualitative effects of branches of river water and availability of

Table 2. Average values of river water index according to OWQI index

Numerical value	Condition	Color
90–100	Excellent	Blue
85–89	Good	Green
70–84	Medium	Yellow
60–70	Bad	Orange
10–59	Very Bad	Red

Table 3. Agricultural water classification according to SAR

SAR	Classification	Quality of Alkaline
< 10	S_1	Low
10–18	S_2	Medium
18–26	S_3	High
> 26	S_4	Very high

Table 4. Agricultural water classification according to EC

EC (µmohs/cm)	Classification	Quality of the soil
100–250	C_1	Low
250–750	C_2	Medium
750–2250	C_3	High
> 2250	C_4	Very high

Table 5. Locations of the stations

Station	Locations of Stations		
	Latitude	Longitude	The Average Height of the Basin (m)
Pole-Sefid (Upstream)	3998373	685267	637
Shirgah (Middle stream)	401878	669383	253
Kiakola (Downstream)	4047543	662205	6

the stations were considered (Fataei et al. 2013). Locations of the stations are presented in Table 5.

Under Study Parameters

The variables studied in this research consist of nitrate, phosphate, total solids, pH, temperature, turbidity, fecal coliform, DO (Dissolved Oxygen) and BOD_5. All of these parameters are measured according to the standard methods (APHA, 2005).

Results and discussion

Table 6 presents the average values of parameters during two periods of wet season and dry season at three zones of upstream, midstream and downstream, during six sampling months at three stations according to available standards.

The values of NSFWQI during two periods of dry and wet season are shown in Fig. 2.

According to NSFWQI, none of the stations at all sampling months had a good or excellent water quality and at best conditions. Station No.1 which is less polluted and does not have any wastewater discharge during the two periods, has just a moderate quality. The reasons for this are natural low value of pH in the Talar River, irrigation of upstream agricultural lands and entry of chemical fertilizers, pesticides and manure into the stream (Banjaka et al. 2012). The values of OWQI during two periods of dry and wet season are shown in Fig. 3.

The OWQI value at all of the stations in all sampling months was between 15 and 20 that is an indicator of "very bad" water quality hencethe Talar river water is not suitable for fishing and recreational purposes (Boskidisa et al. 2011).

Table 6. Average results of parameters during periods of wet season and dry season

Parameter	Wet season			Dry season		
	Upstream	Middle stream	Downstream	Upstream	Middle stream	Downstream
DO (mg/L)	7.31	8.05	4.183	8.96	9.16	5.45
BOD_5 (mg/L)	0.5	0.78	0.583	0.65	1.31	6.11
TS (mg/L)	3211	2889.5	2664.16	1794.41	747.16	1382.83
Turbidity (NTU)	1022.11	2398.66	2260.83	338.5	715.83	536.76
Temperature (°C)	-1.41	2.33	4	9.83	16	17.83
pH	8.13	8.15	8.13	8.16	8.05	8.08
Fecal coliform (Colony/100ml)	1047.16	2366.66	2160	1585	3016.66	2466.66
Nitrate (mg/L)	5.11	5.075	4.0	3.73	9.63	7.51
Phosphate (mg/L)	0.113	0.253	0.236	0.173	0.181	0.205

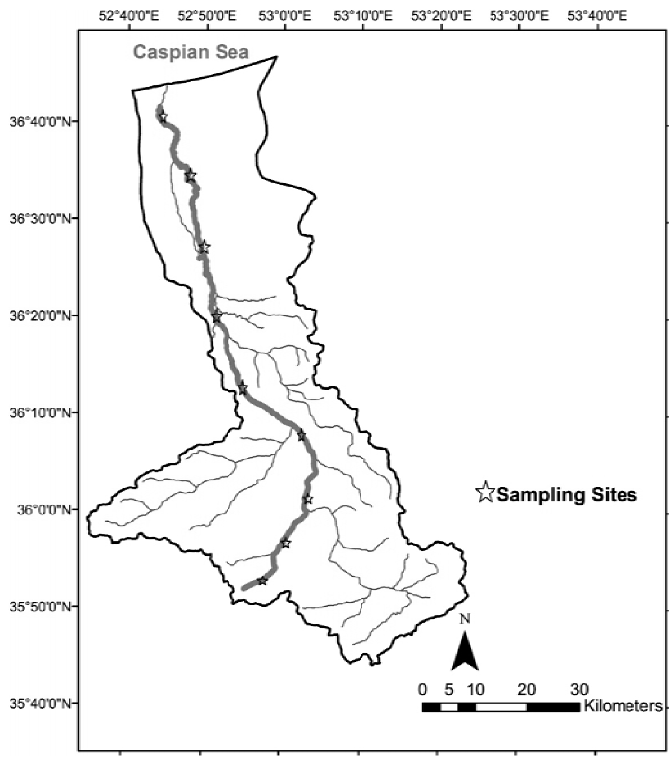

Fig. 1. Location Map of the Talari River in Mazandaran province

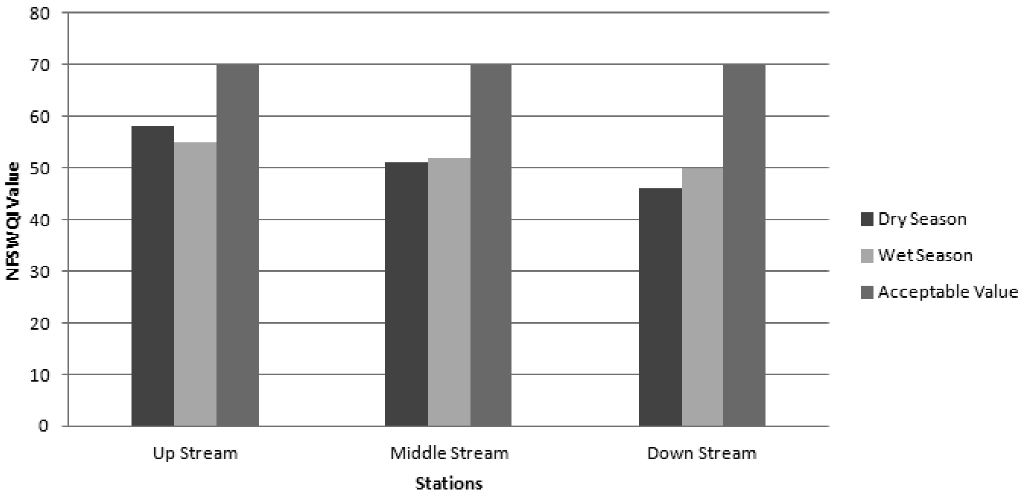

Fig. 2. NSFWQI changes trend in the Talar river

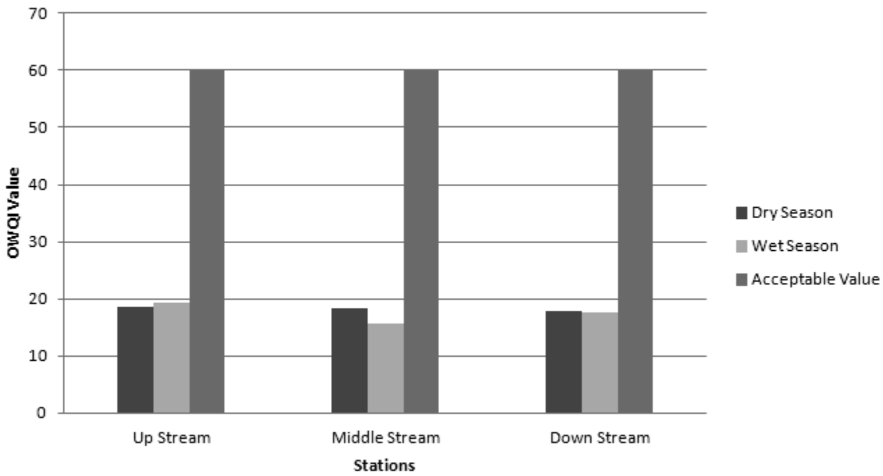

Fig. 3. OWQI changes trend in the Talar River

Comparison of OWQI and NSFWQI changes trend in various periods

OWQI and NSFWQI changes trend in wet and dry seasons at various stations are shown in Figs 4 and 5.

The comparison of OWQI and NSFWQI showed that NSFWQI is more suitable for the Talar river zoning, because it well shows the entering of pollution into the river along its pathway during sampling months. Also because of weighting parameters that are involved with NSFWQI, this index is distinct from OWQI. The study of Hooshmand in 2009 confirms this result that NSFWQI has a higher efficiency in comparison with OWQI (Hooshmand et al. 2009). Also, Fabiano in 2008 investigated the NSFWQI on the Macaco and the Kiocsada Rivers and the results of this study showed that NSFWQI is an acceptable indicator for zoning of the both studied rivers (Fabiano et al. 2008). Also, the study of Simeonov et al. in 2003 conducted on surface water quality of Northern Greece showed that by least treatment the water in this condition can be potable (Simeonov et al. 2003).

Wilcox numerical value

The amount of Wilcox indicator at study stations is presented in Table 7.

According to Wilcox, in each period, the water pollution is decreased from upstream to downstream and conversely, water quality is increased because of EC and SAR reduction. Also, the water samples from the river in all sampling months and stations showed that the Talar river water is in S_1 condition (low alkalinity) and C_2–C_3 classes, according to SAR and EC, respectively. Generally, based on Wilcox the Talar river water is pretty suitable for agriculture in all sampling months and stations (Kowalkowski et al. 2007).

Conclusions

Population load and excess urban activity in the basin of this river, industrial activities, excessive consumption of chemical fertilizers and pesticides, discharge of rural, urban and industrial wastewater and also solid wastes into the river which have a continuous increasing trend are the main source of river pollution. So, human factor is the main cause of river pollution. Besides human factors, natural factors such as low rainfall, water consumption for agricultural and industrial purposes, development of agricultural lands at the expense of natural lands wastefulness and finally, increased physical and chemical pollution of the river that leads to

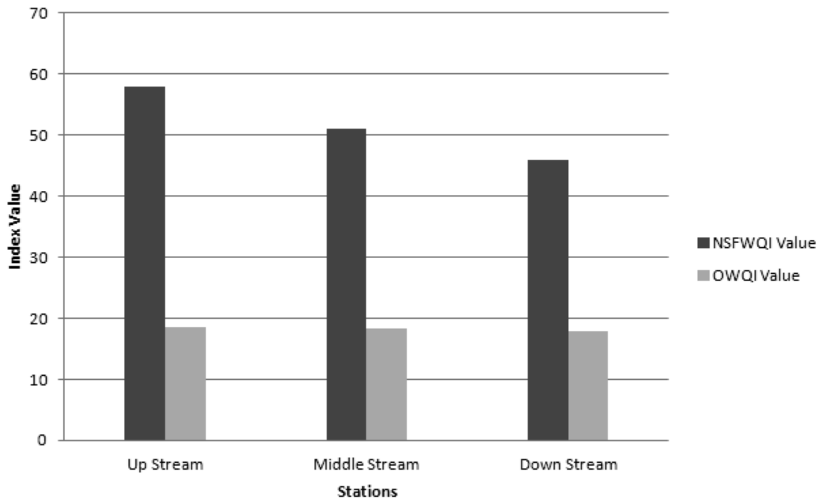

Fig. 4. Comparison of OWQI and NSFWQI changes trend in wet season

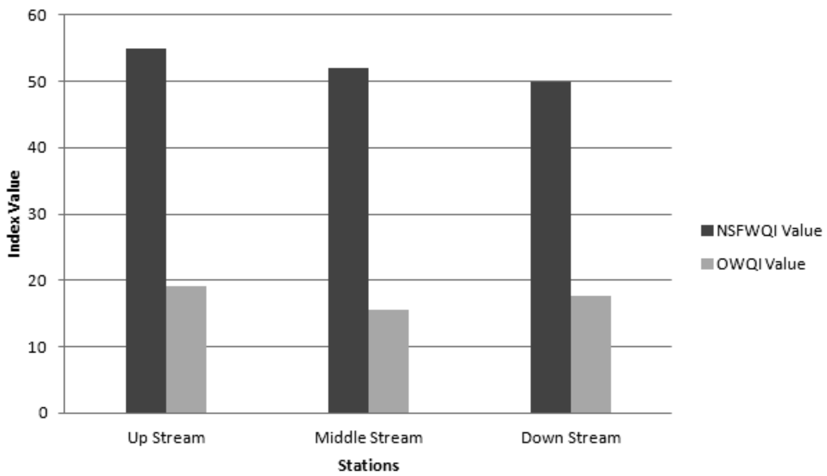

Fig. 5. Comparison of OWQI and NSFWQI changes trend in dry season

Table 7. NSFWQI water quality index in two periods of wet and dry season

Stations	Wet season			Dry season	
	Qualitative Condition	Index Value		Qualitative Condition	Index Value
Up stream	Average	58		Average	55
Middle stream	Average	51		Average	52
Down stream	Bad	46		Bad	50

natural disruption of its biological and bioavailability capacity.

In this study, the river water quality is different for OWQI index and NSFWQI index. The reason for this can be due to the fact that OWQI is stricter than NSFWQI. According to OWQI, the DO, BOD_5 and turbidity at station No.1 are at acceptable values of standards and there is no wastewater discharge into it, but, because of high nitrate and phosphate contents (due to the use of chemical fertilizers and pesticides at upstream), low pH and interactions between these parameters, station No.1 does not have a good quality water (Saha 2010). In terms of drinking purposes, water quality at station No.1 was better than in other stations and by least treatment and pH adjustments it can be potable. But water at other stations needs more advanced treatment to become acceptable for drinking purposes (Wongsupapa 2009).

According to the studies which present the current conditions of the Talar River, three conclusions can be considered:

Generally, it comes from the interpretations of the results based on NSFWQI that along the Talar river pathway from upstream station to the outlet of the Caspian Sea, the pollution load is increased and water quality is decreased. The NSFWQI value at upstream station was more than 50 and at down-stream station (in both periods) was less than 50, which is indicator of bad conditions. So, according to NSFWQI, the average quality of the Talar river water is moderate.

Table 8. OWQI index in two periods of wet and dry season

Stations	Wet season		Dry season	
	Qualitative Condition	Index Value	Qualitative Condition	Index Value
Up stream	Very bad	18.62	Very bad	19.22
Middle stream	Very bad	18.42	Very bad	15.58
Down stream	Very bad	17.89	Very bad	17.68

Table 9. Wilcox value at study stations in wet and dry seasons

Station	Wet season		Dry season	
	Qualitative Index	Qualitative Condition	Qualitative Index	Qualitative Condition
Upstream	C_3S_1	Medium	C_3S_1	Medium
Middle stream	C_2S_1	Good	C_3S_1	Medium
Downstream	C_2S_1	Good	C_2S_1	Good

According to the results of the OWQI index experiments, the water quality of the river is in "very bad" condition so the Talar river water is not suitable for fishing and recreational purposes.

Based on Wilcox index, the Talar river water is suitable for agricultural purposes in entire river and on every day of the year.

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