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ORIGINAL ARTICLE

Qualitative Zonation of Water Using the Quality Indicators (The case study: Siyahab and Gazmahale Rivers)

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ABSTRACT
Rivers are considered as one of the main sources of water supply for a variety of uses including agriculture, industry and drinking. Therefore, monitoring the quality of these resources is seen one of the important tasks in the field of environmental management due to recent droughts, urban and rural development. In this study, which is a descriptive-sectional type, the seasonal sampling was carried out from six Siyahab and Gazmahalleh river stations in a one-year period from April 2015 coincided with the hot, low water, cold & rainy seasons. The parameters measured such as temperature, electrical conductivity, dissolved oxygen, PH, turbidity, BOD and COD along with the concentration of main anions and cations and microbiological parameters. The given data of study were analyzed using the National Quality Index NSFWQI, Indian Pollution Control Commission and ion ratio. The analysis of measured parameters according to NSFWQI index suggests that in both rivers, the total quality index in the first six months is more than 50 and represents an average quality. And in the second half is less than 50 and indicative of poor quality. The classification and determination of the quality of the water of river is almost consistent with the results of NSFWQI according to the standard of Central Commission of Indian pollution control. By physical, chemical, biological monitoring as well as controlling the national index of water quality and above charts in the desired stations, the environmental impacts of pollution was evident in different parts of the river; and provide the ability for relevant authorities to make decisions about how to use water in various parts.
Keywords: *Water Quality Index, Decision Making, Indicator*

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INTRODUCTION

Rivers and flowing waters have traditionally been needed and attended by human societies and established for the benefit of water resources, urban, industrial and agricultural centers in the vicinity of rivers. This also provides the essential requirements and meets the needs of agriculture and transportation. Increasing water demand, raised living standards, expanded contamination of water resources as a result of developing agricultural, urban and industrial activities caused the environmental predicament and the intensified pollution of water resources and made its logical and rational management extremely difficult and complex [1].

surface waters more than other waters are exposed to pollution followed by rain, especially heavy showers, various particles of plant, animal and even industrial and toxic are transported by water and contaminated the water [2].

Since human factors (industrial contaminants) increases the concentration of pollutants in the water of rivers and assuming natural mechanisms such as physical and chemical properties of water and self-purification of rivers will have a major contribution to control or intensify these concentrations. The first step in determining water quality of rivers is the awareness of water quality changes in the temporal and special dimensions and also to determine the main sources of water pollution [3, 4]. Today, holistic and systemic treatment in quantitative and qualitative management of water resources has a particular importance due to the increase of components of those systems and communication complexity and their

mutual interaction. To this aim, two rivers were randomly considered in the province of Golestan to study and investigate the qualitative parameters as well as the environmental impacts [5,6].
The research conducted on water quality changes of Siyahab and Gazmahale rivers in Iran, the Amazon and Yukan in Brazil as well as surface flow in the state of Nevada in USA has shown that the way of using the surrounding lands of rivers have a considerable impact on the sort and amount of its pollution and changes [7-8].
In this study, we used the method of water quality indexing to express the water quality of Siyahab and Gazmahale River. The index 1 NSFWQI is selected because of its simplicity and breadth of application as well as the availability of required parameters. In this study, examples of applying these indices are reviewed. We used the index of NSFWQI for the quality ranking of different rivers .
In this study, by physical, chemical, biological monitoring as well as controlling the national index of water quality and mentioned charts in the desired stations, the environmental impacts of pollution was investigated and provide the ability to make decisions about how to use water in various parts for relevant authorities.

MATERIALS AND METHODS

Golestan province with an area of 22000 km^2 is located in the north- eastern part of the country. This province is at neighboring of the Caspian sea (Mazandaran) from the north, Khorasan province from the east, Mazandaran province from the west, and Semnan province from the south. It is located at the geographical range of 54 degrees to 56 degrees of east longitude and 36.30 to 38.15 north latitude. Two main rivers that were examined in this study are Siyahab and Gazmahale rivers.

The Specification of Siyahab River

This river is one of the major rivers that enter the wetland. The most water flow occurs in the March & April which caused by the heavy rainfall and lack of water discharge for various uses. This river has the least water flow in the first six months (May to Oct) and the most water discharge in these months of year is especially for agricultural use. The shortage of rainfall in these months contributed to this in a way that Siyahab River has the lowest water flow in the quarter of year. The maximum of water flow is 3.96 cubic meter per second, the min 0.22 cubic meter per second and the average of its water flow is 1.75 cubic meter per second annually. The capacity of entering water to Gorgan gulf is 55.2 million cubic meter. Anyway, this river's water flow has heavy fluctuations i.e. between peak of 9 meter cube per second in March and Min zero during the summer each year. The reduction of water flow leads to extra concentration of pollutions and endangers self-purification of rivers.

Specification of Gazmahale River

The length of this river is around 180 kilometers and the scope of its catchment area is 300 square kilometer. The river water is permanent. Its discharge rate at a 23-year period is 148.3 million cubic meter per year. The catchment area of river is all in the mountanous area of north and its northern planes are covered with forest trees.
To determine the quality of water of these rivers and their zonation, the required physical and chemical factors measured in the sampling stations which their coordinates expressed in table 1.

Table 1: the coordinates of sampling stations

height	Width	Length	The sign of station	Name of river
16	3454657	253221	A	Siyahab
23	3559822	263270	B	
100	3581935	266613	C	
38	3495867	246592	D	Gazmahalleh
25	3477943	253768	E	
150	3570381	239940	F	

The investigation of water quality of studied stations were conducted by using the national quality index (NSFWQI), the classification of waters using the Indian commission of pollution control and the study of ion standard deviation.

1. The classification of waters according to the national water quality index (**NSFWQI).**

The quality indicators of pollutions are the methods which can be used as a powerful management tool for relevant decision making. Table 2 shows the measured parameters of desired stations.

Table 2. Measured parameters in the desired stations

Sampling variable	*Abbreviation*	*Measuring unit*	*Measuring device*
Water temperature	T	c	Digital thermometer
biological oxygen demand	BOD_5	Mg/l	Mercury column method
The chemical oxygen demand	COD	Mg/l	Titration with thiosulfate solution sodium In the presence of an alkaline iodide
Electrical conductivity	EC	µSiemens/cm	EC Digital meter
Turbidity	Turbidity	NTV	DR-2800
acidity	PH	-	PH Digital meter
Fecal coliform	FC	Total coliform in 100 ml	MPN method
Total coliform	TC	Total coliform	MPN method
phospate	PO_4^{3-}	mg/L	DR-2800
nitrate	NO_3^-	mg/L	DR-2800

Brown and his colleagues developed a quality index of reduction and National Water Quality Index (NSFWQI) was presented in 1970 with the support of US National Health. They first introduced about 35 Pollution Parameters and then selected about 9 parameters according to the experts to create the main index including the following parameters: BOD5, dissolved oxygen, fecal coliform, nitrates, PH, temperature changes, total solids, total phosphorus, turbidity or turbidity. The use of this index is very popular and considered a complete and comprehensive index for the quality classification of surface water in drinking. And by using it, we can achieve proper vision about water quality of rivers. NSFWQI index is obtained using equation (1):

$\sum W_i \, I_i$= NSFWQI

Ii = sub-index i, Wi = weighting coefficient of i. After measuring the above characteristics, each sub-index is obtained from the conversion curves which by these curves, the parameters are converted to 0-100 standards. In this method, for calculating the total index of each obtained sub-index curves multiplied by weight factor. The sum of the equation (1) obtained final index. The sum is obtained according to equation (1) of final index.

The classification of water according to the standards of Indian Central Commission for Pollution Control. The quality classification of surface water is given in the table (6) according to two parameters of dissolved oxygen and required oxygen for biological activities by the Indian Central Commission for Pollution Control.

(A): the sources of drinking water without conventional treatment and after disinfection (B): For sanitary purposes, bathrooms, swimming and recreational uses, (C): the sources of drinking water after conventional treatment, (D): used in wildlife, fishing and etc (E): for irrigation, cooling of industrial plants and waste water control.

Table [3] the quality classification of surface water according to the standard of Indian Central Commission for Pollution Control

	The Classification				
mg/L	A	B	C	D	E
DO	>6	>5	>4	>4	4
BOD	<2	<3	<4	<6	>6

The Study Of The Ionic Deviation Coefficient

The Ion deviation coefficient (α) determined from the following equation:

$$\frac{\sum \, {}^{meq}/_{L} \text{ Anions} - {}^{meq}/_{L} \text{ Cations}}{\sum \, {}^{meq}/_{L} \text{ Anions} + {}^{meq}/_{L} \text{ Cations}} \times 100$$

If water samples are α<0.05, then the water analysis has problem or water has a special case, considering different stations, diagram of the ion balance of samples is drawn and the value of Coefficient (α) is calculated.

Given that the value of this coefficient is less than (α), the water analysis is a correct value. And also we can relate the slightly difference to the amount of existed cations and anions in the water that were not measured in this study including the NH_4 and Fe or the error resulted from the measurement.

RESULTS

The classification of pollution intensity (Table 4) was done by measuring parameters outlined in table 1, and the calculation of final index using the formula 1 and calculated the weight factor of quality water index (table 5) [10].

Table 4: The Classification of river pollution intensity based on index (NSFWQI)

The status of water quality	class	Calculated index
great	A	91 – 100
good	B	71 – 90
average	C	51 – 70
bad	D	26 – 50
Very bad	E	0 – 25

Table 5: Weighted Factor of Index (NSFWQI)

PO_4^{3-} (mg/l)	TS (mg/l)	T (centigrade)	PH	NO_3^- (mg/l)	Coliforms Fecal	DO (mg/l)	BOD (mg/l)	Turbidity	parameters
0.10	0.07	0.10	0.11	0.10	0.16	0.17	0.11	0.08	Weighted factor

The value of Water Quality Index is calculated according to the American National Health Organization for all stations. As you can see, water quality of both rivers in low water and upstream seasons have better condition in terms of quality index and it is in the middle class in terms of water pollution. But the quality index dropped in the high-water seasons and downstream stations because of the distribution of agricultural and social activities around the river and placed in the bad class.

Table (6) The determination of quality of river according to index (NSFWQI)

NSF index in high-water season	NSF index in low water seasons	Sign of station	Name of the river
43.35	52.26	A	Siyahab
44.55	51.17	B	
44.86	56.45	C	
44.76	50.38	D	Gazmahalle
47	53.65	E	
48.04	54.39	F	

By comparing the amount of DO and BOD existing in the samples of water in Gazmahalle & Black water rivers, the results of surface water quality classification obtained according to the standard of Indian Central Commission of Pollution Control in the table (7) **.**

High water seasons	Low water seasons	Sign of station	Name of river
A-C	A-C	A	Siyahab
A-B	A-C	B	
A-B	A-C	C	
A-D	A-D	D	Gazmahalle
A-E	A-E	E	
A-C	A-C	F	

Table (8) the quality determination of the water river according to the standard of Indian Central Commission of pollution control

Ion deviation coefficient was calculated from the formula 2 which the results are expressed in Table 8 **.**

Table (8) deviation factor (α) at different stations

High-water seasons	Low water season	The name of river
2.15	4.3	Siyahab
5.9	5.3	Gazmahalle

DISCUSSION AND CONCLUSION

The first step to identify and estimate the amount of pollution that is transferred via rivers to the sea is to identify the type and capacity of pollutants and their physical and chemical composition existed in their water [12]. As there are not much studies and researches to assess the quality of the water of rivers in terms of quality grading, using the NSFWQI technique as a simple method for early recognition of rivers' quality and can be used by managers and engineers to make planning for quality protection. Regular monitoring of rivers purposefully and based on proper planning and design, then its ranking by the use of quality index provide the access to qualitative transformation and forecast the reduction measures of pollution in the river basin for managers and officials [13]. The analysis results of measured parameters according to NSFWQI index suggests that the Total Quality Index in both rivers in the first six months coincide with the low water seasons between 50 and indicates the average quality and in the second six months which is coincided with the high rainy season , between less than 50 and indicates the bad quality. In N.S.F method which simultaneously investigate a set of physico-chemical parameters such as dissolved oxygen and biological parameters such as BOD and microbiological parameters, the quality of all three rivers have adverse conditions particularly in downstream. Also, the comparison of classification results and determination of the river quality according to the standard of Indian Central Commission of pollution control shows that it is nearly consistent with the results of N.S.F. [2, 14].

The qualitative data of stations indicates that in the agricultural uses, the low SAR water is suggested because for a certain amount of sodium cation, the increase of cations of calcium and magnesium of water leads to the ability of Sodium absorption by soil, and therefore it is less harmful to the plants [15]. But sodium cannot be used only as water quality criteria in terms of agriculture and it is better that the effect of water be considered in conjunction with the total Salinity of water. Therefore, the horizontal axis is dedicated to water salinity (in μSiemens/cm) and the vertical axis to SAR sodium adsorption ratio according to Wilcox classification method. Black water river samples are placed in Class C2-S1 (slightly salty- suitable for agriculture) and Gazmahalle river water samples placed in class C3-S1 (salty- suitable for agriculture) in low water and rainy seasons. Generally speaking, the results of this study indicate that water quality in the Siyahab River and Gazmahalle are not changing a lot during different months of season. But pollution of river from upstream to downstream has increased dramatically and the quality of river water is reduced, which represents the entrance of domestic, agricultural and industrial waste water to the river. To protect these water resources from contamination, the need for implementation of rules and strict instruction to ensure public health and preserve the water resources for next generations.

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