Abstract

Background: Zoning of the water quality based on NSFWQI index is used more than other indices. The purpose of this study is to evaluate the water quality of Kashan’s Ghohrood River, using National Sanitation Foundation Water Quality Index (NSFWQI) and its zoning with Geographic Information System (GIS).

Materials and Methods: In this study, water quality parameters of Ghohrood River are studied monthly in five different stations from October 2014 to September 2015 during 12 months in Kahsan central of Iran. Also, these data were analyzed with NSFWQI index, and finally route of river was zoned using GIS software.

Results: Among the studied stations, station A had the highest and best rate of water quality by 86.87% in March. Water quality index was 60.93% in station E in August. Average studied index in stations A, B, and C in all of the months was 72-80 and in stations D and E average index was 67-69. Average index of NSFWQI had a downward slope in the warm months; so that, in the summer, the index was lower than other seasons in each station.

Conclusion: Results showed that water pollution increases by increasing the distance between source of the river and station. Since the area is considered as a recreational resort especially in the spring season and the fact that around the river is used as pastures, water quality deterioration especially in D and E stations is a very important issue.

Keywords: Geographic Information System, Ghohrood River, NSFWQI, Parameters, Stream sanitation
Introduction

Rivers as one of the most important sources for supplying water and transferring water for industrial, agricultural, and municipal consumption are very significant. Growth of population and pollutions due to evacuation of urban, industrial, and agriculture sewages, leachate of waste disposal sites, and surface runoff cause the spread of pollution and the limitation of available water resources. Monitoring and control of surface water for its various usages are necessary to provide high quality water for various uses available of consumers. Along with the improvement and development of technology, more information is easily available to human in a shorter time. Zoning the water quality of rivers is considered as the first and the most important stage in surface water quality management. Also, recognizing quality of surface waters for different uses is necessary. Identifying the polluted areas and pollutants cause optimum and proper consumption of water in various consumptions.

Data of surface waters must be analyzed and the summarized result must be presented to experts for different applications. One of the very simple methods that has no mathematical and statistical complexities and can explain the water quality, is water quality indices. Pollution quality indices are the methods used as a powerful management tool for making decisions in water quality management.

One of the most common used and simple quality indices in the world is National Sanitation Foundation Water Quality Index (NSFWQI) that plays an important role in water quality investigations because of its simple and understandable explaining of the results. This index is determined based on pH, BOD, TS, DO, turbidity, temperature, phosphate, nitrate, and fecal Coliform. After measuring these factors, a weight or a value number is assigned to each of parameters and the sub-indices are obtained by curved conversions and finally mathematical relations are used for the calculation of final index the index NSFWQI is an index with reduction scale, in other words, index value reduces by increasing the water pollution rate and finally water quality is calibrated. Researchers found that NSFWQI and WQI indices were the best indices for monitoring surface water quality. dos Santos Simões F et al. investigated on Macuco and Queixada rivers concluded that WQI index is a proper index for zoning water quality of these rivers and showed the critical stations of these two rivers which required strong control and management.

According to the studies in Iran and other countries in the recent decade, NSWQI index has been considered as a suitable and even the best water quality index for assessing and monitoring the surface water such as rivers, lakes, ponds, and tanks. Also, they stated that a good knowledge of the quality of rivers water can be obtained by using it. On the other hand, pollution zoning, and presenting the correct image of surface water quality by using the Geographic Information System (GIS) provide more information and awareness for managers on order to better decision making on surface waters. Ghohrood River is considered as an important source of surface water. It is located in the south of Kashan, central of Iran. Ghahroud River is a shallow water and is used by livestock and wildlife so it can be infected by a variety of infectious agents.

It is one of the important shallow and permanent rivers of the area with the flow rate of 110 m³/min that originates from Kolahbarfi Mountains with the height of 3227 meters and after passing Ghohrood, Juveinan, and Muslimabad villages, enters the Kashan plain. Villages around this river have no sewerage system and, in some positions, municipal and rural sewageries enter into the river and this is a great threat to the quality of the river water. The purpose of this study is to determine the pollutants rate along the river and giving a clear zoning quality system by using the GIS for management decision makings.

Materials and Classification of river water based on water quality index

This study is a descriptive and cross-sectional one in which water quality of the Ghohrood River are monitored and controlled 5 stations along it by using the specified index was monitored and controlled. For this purpose, first, the general location of the river was considered by using a map having the scale 1.50000. Then, the stations were selected by studying on the river trail according to the location of pollutants inlet and the possibility of the sampling. After selecting the study points, latitude, longitude and height of the sampling points were determined via GPS. Table 1 shows Overall characteristics of sampling stations along Ghohrood River of Kashan.

All microbial samples were collected in 300 ml glass jars, also all non-microbial samples were collected in 500 ml plastic jars. Transportation, maintenance and experiment of samples were performed according to a Standard Method. In this study, nine physical, chemical and biological parameters were examined for NSFWQI index including dissolved Oxygen (DO), biological Oxygen demand (BOD), pH, nitrate (NO₃⁻), phosphate (PO₄³⁻), turbidity, temperature (T), fecal coliform (FC), and total solids (TS). Dissolved Oxygen rate was measured by titration volumetric with the incubator. Concentration rate of nitrate was measured according to the Standard Method. Turbidity of samples was evaluated in the laboratory with a turbidimeter HACH 2100N. Fecal Coliform was measured by nine-tube MPN method and medium of cultivate specialized for probabilistic, confirmatory, and complementary methods. BOD of samples was measured by 2 times evaluation of DO, initially (the first day) and secondary (the fifth day) with volumetric method and incubator. Total solids of samples was determined by the Standard Method and at temperature of 103-105°C in oven and the temperature was determined with mercurial thermometer.
parameters and concentrations for calculating NSFWQI index rate were obtained via Water Quality Index software. In this study, experimental results were analyzed with SPSS software version 16.0 for windows and then for each station water quality index was calculated by using tables, graphs and WQI calculator software. First, water quality value of parameter was determined based on the related curve and then its result was multiplied by their weight factors and finally NSFWQI was calculated using the software and was studied by the related interpretation tables. In NSFWQI method, for calculating the final index, the following equation was used:

$$NSFWQI = \sum_{i=1}^{n} W_i Q_i$$

Where $W_i$ is weight or priority degree parameter which varies from 0 to 1. $Q_i$ is grade or parameter quality that varies from 0 to 100. WQI is water quality index that varies from 0 to 100.

In this index, the lowest weight refers to total concentration of water solids with the rate from 0.07 unit and the highest refers to water’s dissolved Oxygen concentration with the rate from 0.17 unit.

For preparation of the map and zoning with the defined indices, first the sampling stations was chosen and then their geographical coordinates were set by Oregon 550 GPS. This setting was in XYZ form with UTM format. After picking the coordinates, final changes of data were performed in Arc GIS software and finally the output was obtained as numeral layers with point format. Then, interpretation table of sampling points were updated.

**Statistical Analysis**

Data were analyzed by statistical analysis of variance (ANOVA) with 95% confidence level.

**Results**

Obtained results from experimental evaluation of nine parameters of DO, BOD$_5$, TS, pH, nitrate, phosphate, temperature, total solids and fecal Coliform in different periods of time and different stations are shown in the following tables and Figure 3. NSFWQI index rate during the study time is shown in Table 3 according to the result from the experiments. According to the below table and the numerical rate of NSFWQI index, water quality during the study time depending on the months and stations, varies from average to good. In this study, the average annual NSFWQI index is stations A, B, C and D is 80.80, 77.28, 72.11, 69.88, and 67.46, respectively.

**Table 1. Total water quality result of Kashan’s Ghohrood River according to NSFWQI index during the study time in the selected stations**

| Months    | Stations | A  | B  | C  | D  | E  |
|-----------|----------|----|----|----|----|----|
| October   |          | 78.62| 74.54| 72.28| 70.7| 69.48|
| November  |          | 80.23| 77.24| 72.78| 65.79| 68.15|
| December  |          | 84.46| 80.09| 73.25| 70.86| 71.31|
| January   |          | 84.03| 79.38| 77.09| 73.77| 72.93|
| February  |          | 83.81| 77.5| 74.56| 73.63| 68.43|
| March     |          | 86.87| 82.08| 75.56| 69.25| 68.34|
| April     |          | 80.27| 79.11| 70.03| 71.5| 64.95|
| May       |          | 76.47| 78.24| 74.13| 71.43| 67.76|
| June      |          | 81.81| 79.14| 72.5| 71.25| 66.72|
| July      |          | 79.7| 75.52| 69.4| 69.3| 66.11|
| August    |          | 76.15| 71.01| 62.75| 63.24| 60.93|
| September |          | 77.19| 73.57| 71.07| 67.86| 64.5|

The results of our study show that the rate of nine parameters of DO, BOD5, TS, pH, nitrate, phosphate, temperature, total solids and fecal Coliform in all stations are different. Also, these parameters are variable in different locations along the river. The rate of these parameters at different time and different stations are shown in the Table 1 to 4 and Figure 1. According to the result of the experiments, NSFWQI index rate during the study time is shown in Table 1.

**Table 2. Minimum and maximum experimental data parameters and their details based on parameter numerical rate, station name and month**

| Parameter          | Minimum | Maximum |
|--------------------|---------|---------|
|                    | Rate    | Station | Month  | Rate    | Station | Month  |
| DO (mg/L)          | 3.48    | E       | August | 7.85    | A       | March  |
| BOD (mg/L)         | 0.10    | A       | February | 7.15    | E       | April  |
| Phosphate (mg/L)   | 0.03    | B       | November | 0.61    | C       | March  |
| Nitrate (mg/L)     | 0.43    | A       | December | 0.64    | A       | May    |
| pH                 | 6.51    | E       | June   | 8.04    | A       | September |
| Temperature [C]    | 2.23    | A       | March   | 12.5    | E       | September |
| Total solid (mg/L) | 11.24   | A       | November | 41.4    | E       | February |
| Turbidity (NTU)    | 0.6     | A       | March   | 8.19    | C       | April  |
| Fecal Coliform (MPN/100mL) | 0       | A       | December | 1100    | E       | April  |
Table 3. Average and standard deviation of different parameters of Kashan’s Gohrood River water based on the studied stations

| Area | Chemical parameters | Physical parameters | Biological parameter | Index |
|------|---------------------|---------------------|----------------------|-------|
|      | PH | NO<sub>3</sub> (mg/L) | PO<sub>4</sub> (mg/L) | BOD (mg/L) | DO (mg/L) | TURB (NTU) | TS (mg/L) | TEMP (°C) | FC (MPN/100mL) | NSFWQI |
| A    | 0.46 ± 0.33 | 0.05 ± 0.49 | 0.049 ± 0.094 | 0.56 ± 0.94 | 0.79 ± 6.24 | 0.4 ± 1.08 | 4.1 ± 17.2 | 2.3 ± 6.08 | 7.25 ± 15.67 | 80.80 ± 3.44 |
| B    | 0.33 ± 0.23 | 0.02 ± 0.48 | 0.17 ± 0.176 | 0.54 ± 1.39 | 0.47 ± 5.75 | 1.1 ± 2.34 | 4.3 ± 18.4 | 2.5 ± 6.79 | 22.15 ± 32.92 | 77.27 ± 3.10 |
| C    | 0.27 ± 0.35 | 0.17 ± 0.47 | 0.14 ± 0.21 | 0.66 ± 2.88 | 0.49 ± 5.43 | 1.8 ± 6.02 | 5.3 ± 24.5 | 2.3 ± 7.68 | 81.2 ± 105.6 | 72.11 ± 3.68 |
| D    | 0.35 ± 0.26 | 0.17 ± 0.47 | 0.51 ± 0.25 | 0.98 ± 3.24 | 0.59 ± 5.11 | 1.3 ± 1.87 | 14 ± 33.8 | 1.4 ± 9.15 | 75.4 ± 109.8 | 70.36 ± 3.29 |
| E    | 0.1 ± 0.52 | 0.53 ± 0.66 | 0.08 ± 0.188 | 1.37 ± 3.33 | 0.61 ± 4.73 | 1.7 ± 2.84 | 11.4 ± 41 | 1.6 ± 9.67 | 291 ± 223.83 | 67.47 ± 3.18 |
| P value | >0.01 | >0.1 | >0.1 | >0.001 | >0.001 | >0.001 | >0.001 | >0.01 | >0.001 |

Table 4. Average and standard deviation of different parameters of Kashan’s Gohrood River water based on the studied months

| Month     | Chemical parameters | Physical parameters | Biological parameter | Index |
|-----------|---------------------|---------------------|----------------------|-------|
|           | pH | NO<sub>3</sub> (mg/L) | PO<sub>4</sub> (mg/L) | BOD (mg/L) | DO (mg/L) | TURB (NTU) | TS (mg/L) | TEMP (°C) | FC (MPN/100mL) | NSFWQI |
| October   | 7.38 ± 0.55 | 0.51 ± 0.47 | 0.11 ± 0.04 | 0.93 ± 1.35 | 0.57 ± 0.65 | 2.9 ± 3.02 | 24.6 ± 11.2 | 9.74 ± 0.69 | 100 ± 87.8 | 73.11 ± 3.6 |
| November  | 6.90 ± 0.45 | 0.53 ± 0.25 | 0.05 ± 0.05 | 1.35 ± 0.65 | 0.67 ± 0.88 | 2.6 ± 2.8 | 23.4 ± 12.3 | 7.14 ± 0.4 | 57.2 ± 38.6 | 72.8 ± 6.03 |
| December  | 7.24 ± 0.32 | 0.42 ± 0.29 | 0.25 ± 0.25 | 2.00 ± 0.86 | 0.52 ± 0.46 | 2.6 ± 2.8 | 23.4 ± 12.3 | 7.14 ± 0.4 | 14.8 ± 9.09 | 76.02 ± 5.9 |
| January   | 7.26 ± 0.47 | 0.47 ± 0.36 | 0.16 ± 0.14 | 2.84 ± 1.48 | 0.58 ± 0.60 | 3.04 ± 2.37 | 26.3 ± 8.9 | 5.2 ± 2.5 | 29.2 ± 24.78 | 77.4 ± 4.5 |
| February  | 7.26 ± 0.48 | 0.49 ± 0.18 | 0.01 ± 0.04 | 0.95 ± 1.05 | 6.11 ± 0.65 | 2.81 ± 2.9 | 31.4 ± 7.5 | 9.70 ± 2.2 | 87.4 ± 59.2 | 75.58 ± 5.6 |
| March     | 6.98 ± 0.47 | 0.47 ± 0.36 | 0.14 ± 0.24 | 2.80 ± 1.48 | 6.08 ± 1.16 | 3.56 ± 2.8 | 42.1 ± 16.4 | 5.40 ± 4.2 | 40.4 ± 32.16 | 77.29 ± 7.22 |
| April     | 6.68 ± 0.48 | 0.48 ± 0.47 | 0.01 ± 0.14 | 3.78 ± 1.48 | 9.20 ± 0.59 | 3.12 ± 3.19 | 22.3 ± 9.4 | 6.40 ± 1.3 | 1100 ± 441 | 73.3 ± 6.3 |
| May       | 6.92 ± 0.54 | 0.54 ± 0.23 | 0.06 ± 0.07 | 2.92 ± 0.92 | 5.49 ± 0.35 | 2.44 ± 1.7 | 22.6 ± 4.2 | 6.44 ± 1.9 | 82 ± 66.8 | 73.64 ± 4.12 |
| June      | 7.26 ± 0.43 | 0.43 ± 0.22 | 0.01 ± 0.07 | 2.53 ± 1.06 | 5.45 ± 0.29 | 1.83 ± 0.67 | 27.8 ± 9.1 | 7.00 ± 0.6 | 128.8 ± 137 | 74.3 ± 6.1 |
| July      | 7.18 ± 0.42 | 0.51 ± 0.23 | 0.05 ± 0.07 | 2.3 ± 0.87 | 5.26 ± 0.54 | 2.92 ± 2.1 | 22.3 ± 2.1 | 9.16 ± 1.4 | 64.8 ± 62.8 | 72 ± 5.4 |
| August    | 6.92 ± 0.45 | 0.53 ± 0.26 | 0.06 ± 0.08 | 2.61 ± 0.5 | 4.46 ± 0.71 | 3.02 ± 2.17 | 21.2 ± 7.7 | 10.00 ± 1.2 | 127.8 ± 101 | 66.8 ± 6.4 |
| September | 7.42 ± 0.44 | 0.56 ± 0.13 | 0.04 ± 0.05 | 2.1 ± 0.55 | 4.80 ± 0.76 | 2.02 ± 1.36 | 25.7 ± 7.5 | 10.2 ± 1.5 | 100 ± 75.2 | 70.8 ± 4.9 |
| P value   | <0.1 | <1 | <1 | <0.01 | <1 | <1 | <0.001 | <1 | <1 | <1 |
According to Table 3, the average studied index in A, B and C stations in all months is 72-80 and in D and E stations is 67-69. The table also shows that the studied index decreases by increasing distance from station A to station E. Also, according to the table, it can be proved that the highest average of NSFWQI index is in the cold months and always the average index in the warm months is the lowest.

According to Table 1 and based on NSFWQI quality index, it was found that among the studied stations, the station A in March had the highest rate of NSFWQI index (86.87) where it was the best quality and in term of the classification, it is classified as the good quality water. Water quality in station E in August had the NSFWQI rate of 60.93, where is classified as the average quality water. Average index studied had a downward slope in the warm months, and only in August, the average under 70 was observed that means an average quality. Also, the best average index was in January and March.

Discussion

Zoning of the water quality of the Ghohrood River according to NSFWQI index and using GIS system showed that fecal Coliform rate, in terms of comparing among the stations varies conditions in each station. Pollution rate from station C to station E in comparison with 2 previous stations increases, and even in station E, it showed a high pollution rate because of the presence of pollution in the sloppy terminal part of the dam and accumulation of pollution in this part and lack of dredging the terminal part. Since animal husbandry is one of the most widely economic activity of the area’s citizens and also according to the high rate of pollution producing by animals, animal wastes can be considered as an important pollutant. Therefore, this is perhaps the reason of the high rate of fecal coliform in the outlet than in the inlet.

In a study on Haraz river, the pollution rate in downstream of river was more than its upstream and the microbial pollution of river was obvious in all the selected stations specially in the spring. Since presence of the environmental factors, increase in pollution in the river trail is natural unless the self-purification of river is very high but presence of fecal coliform indicates the human activity and increase in pollution. Also, it seems that these parameters increase by warming weather that this is in compliance with our study.

According to the obtained data, rate of changes of phosphate is more than nitrate but totally the data of these two parameters are close together in terms of monthly evaluation. The highest rate of these two parameters are obtained in the warm months but they are not very high. A likely relation between total concentration of nitrogen and phosphor and algae was suggested so that with the concentration of nitrogen and phosphor in the water, presence of algae can be inferred. Accordingly, one reason for algae reduction rate in this river may be the low rate of nitrogen and phosphor but environmental factors can be influenced. Reduction of this nutrient causes the reduction of algae. This indicates that this river and eventually Sheikh Bahaei dam, where are located between stations D and E, are not ready for eutrophication.

In this study, BOD rate increases by increasing the distance. One of the reasons of reduction of producing factors of pollution in the primary stations maybe the mountainous area in where water temperature is near to 0°C and even reduction of industrial and agricultural activities in cold seasons are reasons for river total reduction of BOD rate. BOD rate of the river increases by warming weather in the spring. These results are in accordance with the study on Haraz River so that by increasing pollution and water temperature, DO rate reduced and BOD increased.

Generally, the average BOD of the Ghohrood river water is not high but it has a direct relation with the increase in fecal coliform rate so that by warming weather its rate
increases and has the highest average of increase in the spring.

According to the obtained data, water temperature rate has a direct relation with DO and pH which are chemical factors so that by increasing temperature in terms of monthly average and sampling stations, DO and pH rate decrease. Related results of changes in DO and pH in our study are the similar to the results of a study on India rivers.33

In the winter, total solid rate like turbidity has the highest rate. In terms of measuring the average data of studied stations, total solid rate increases along the river. This result matches with the study on chemical, microbial, and physical parameters of underground and surface waters.34 Increase in total solid along the river maybe because of being washed out river bed and presence of pollution producer sources such as inappropriate discharge of animal, human and agricultural sewerage. It may also be because of lack of timely dredging the Sheikh Bahaei dam where is located before station E. Therefore, it has the highest rate of total solids in comparison with other stations. One of the very important factors that leads to lack of using Sefidrood River water for agricultural applications is the high rate of total solid that causes microbial pollutions.35

Since the area for this experiment is mountainous, average temperature of the water is not high. The main reasons for river increase in water temperature along its trail maybe reduction of the height of stations through the river trail, entrancing human sewerage, and agricultural and husbandry activities. Generally, water temperature of Ghohrood River changes in different seasons as the weather changes and has a direct relation with it. Microbial factor was considered as one of the main reasons for increase in temperature of Bangpakong river but unlike the results of this study in different periods of time in the selected stations, high temperature did not show significant difference in terms of effluents and solid wastes of industrial, municipal and agricultural sewerage.36 It indicated the natural factors are more effective.

According to the obtained data in this study, finally the water of the river and Sheikh Bahaei dam in terms of numerical average of index in the studied stations and months is classified as good quality water with the grade of 73.5.

A research on Khorramrood River indicated that the highest quality of water was in station 1 with the numerical rate of NSFWQI index by 82 in August and November, and the worst water quality was in station 6 with the numerical rate of NSFWQI index by 42 in September.37 A study on the lack of dissolved Oxygen was conducted on the Guadarrama and Manzanares rivers according to NSFWQI. Results indicated that NSFWQI index showed good quality at the beginning of Guadarrama River but at the end the quality was reduced up to an average range. Also, this index reported the average of 65 for Manzanares River.3 NSFWQI water quality index of Mahanadi and Atarabanki rivers and Taldanda channel were evaluated. Results showed that industrial effluents and human activities play an effective role in pollution of these areas.38 Results of these studies are close to our study. Various studies showed the increase in pollution along the rivers trail but the effect of input pollution to the rivers are different, however, in Ghohrood River in addition to human and environmental factors as well as geographical conditions were also very effective.

Data of our study shows the increase in NSFWQI index in the cold months and decrease in the index in the warm months. By comparing the results of this index through sampling stations, it can be concluded that only the stations D and E have an average quality while other stations have a good quality water. However, the station D has the quality of almost good as well.

Conclusion

The results of present study show that water pollution increases by increasing the distance from the studied river headwaters to the last station. Sewerage and waste discharge increase specially in the warm months because the area is considered as a recreational resort and the number of tourists and families increase. Animal wastes and agricultural sewerage are the reasons for reduction of water quality in the stations D and E but by comparing the obtained index data, the water of this river has a good quality and has a better condition in comparison with some other rivers that its water needs conventional treatment for supplying drinking water. Also, Ghohrood River is suitable for pisciculturing and sensitive water species and for recreational purposes such as swimming.

To provide the health and safety of the residents as well as the underground resources, careful studies can be conducted to make a water treatment plant and use the river water for drinking.

Recommendation

To protect the health and safety of the residents and also the underground resources, careful studies can be conducted to make a water treatment plant and use the river water for drinking.

Acknowledgment

Thanks to everyone who helped us with this article.

Conflict of Interest

None of the authors had any personal or financial conflict of interest.

Funding

This study was funded by Deputy of Research of Kashan University of Medical Sciences with grant number 9377.

Ethics Approval and Consent to Participate: Not applicable.
Conflict of Interest: None

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Date of Submission: 2018-08-26

Date of Acceptance: 2018-10-26