Environmental Health Engineering and Management Journal 2015, 2(1), 7–11

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Environmental Health Engineering and Management Journal

Original Article

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Survey of water quality in Moradbeik river basis on WQI index by GIS

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Abstract

Background: Survey of pollution and evaluation of water quality in rivers with Oregon Water Quality Index (OWQI) and GIS are effective tools for management of the impact of environmental water resources. The information in calculating the WQI of Moradbeik river allowed us to take our tests results and make a scientific conclusion about the quality of water. GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale.

Methods: The WQI of Moradbeik river consists of nine tests: Fecal Coliform (FC), Biochemical Oxygen Demand (BOD_5), Nitrates (NO_3), Total Phosphate (PO_4), pH, temperature, Dissolved Oxygen (DO), turbidity, and Total Solid (TS). Water quality of Moradbeik river was investigated for 12 months. Concentrations of these nine variables were normalized on a scale from 0 to 100 and translated into statements of water quality (excellent, good, regular, fair, and poor). Also this data were analyzed with WQI index, and then river basis on water quality was zoning by GIS.

Results: The average of WQI was 61.62, which corresponded to "medium" quality water at the sampling point 1 (best station) and decreased to around 26.41 (bad quality) at sampling point 6. The association between sampling points and water quality indexes was statistically significant ($P<0.05$).

Conclusion: Based on physical, chemical and biological agent monitoring and also with control of water quality indexes of these points, we observed wastewater and other river pollutants.

Keywords: Water quality evaluation, Water quality index, GIS, Moradbeik

Citation: Samadi MT, Sadeghi Sh, Rahmani A, Saghi MH. Survey of water quality in Moradbeik river basis on WQI index by GIS. Environmental Health Engineering and Management Journal 2015; 2(1): 7–11.

Article History:
Received: 3 August 2014
Accepted: 21 November 2014
ePublished: 12 January 2015

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Introduction

Different regions of the world are being faced by different types of problems associated with the occurrence, use, and control of water resources, which may endanger the sustainable development of these resources. The quality of surface waters is a very sensitive issue. Anthropogenic influences as well as natural processes degrade surface waters and impair their use for drinking, industry, agriculture, recreation, and other purposes (1,2). The Water Quality Index (WQI) has been considered to give a criteria for surface water classification based on the use of standard parameters for water characterization (3,4). So chemical, physical, and biological constituents are quantified in all rivers of the world. The problem is the quantity of analysis required and the cost to accomplish them. In order to resolve this problem, regulatory agencies have been creating and using a general index as a management tool. One of the oldest of these tools is the WQI developed by the National Sanitation Foundation (NSF) of United States which is based on the analysis of nine parameters: Fecal Coliform (FC), Biochemical Oxygen Demand (BOD_5), Nitrates (NO_3), Total Phosphate (PO_4), pH, temperature, Dissolved Oxygen (DO), turbidity, and Total Solid (TS). Its output ranges from 0 to 100, where 100 represents perfect water quality conditions while zero indicates water that is not suitable for the intended use without further treatment. This index is a mathematical instrument used to transform large quantities of water characterization data into a single number, which represents the water quality level. The use of WQI is a simple practice, which allows adequate classification of water quality (5,6). The general WQI was developed by Brown *et al* and improved by Deininger for the NSF (7). The Scottish Development Department (SDD) in collaboration with regional institutions for river quality preservation, Solway Purification Board (Solway RPB), the Tweed Purification (Tweed RPB) carried out an extensive research in order to evaluate the river quality in Scotland according to an NSF study (8). Horton suggested that various water quality data could be integrated into an overall index. Over the years many indices have been calculated, each for its own purpose as follows: Dalkey, Liebman, Prati *et al*, O'Connor, Harkins, Walski and Parker, Inhaber, and Service for Rhine Pollution Monitoring (RPM) (8). The purpose of the Oregon Water Quality Index (OWQI) was to improve understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends. Although some information is lost when integrating multiple water quality variables, this loss is outweighed by the gain in understanding of water quality issues by the public and policy makers. Improved understanding is very important to water resource managers in terms of increased support for water resource improvement efforts. The science of water quality has improved markedly since the introduction of OWQI in the 1970s (8). OWQI was improved in 1995 to reflect advances in the knowledge of water quality and designing water quality indices. The primary purpose of this report is to describe the historical basis and define the improved design of OWQI. Improved OWQI is widely used and maintained by Oregon Department of Environmental Quality (DEQ). OWQI has been used to report water quality status and trends in Oregon to state legislators and other water resource policy makers via presentations and to the public through reports accessible on the internet. OWQI has been used as a supplement to more traditional reporting formats, such as Water Quality Status Assessment (305(b)) Report (9) and the annual McKenzie Watershed Water Quality Report (9). The quality of water is equally important as its quantity. Remote sensing and GIS are effective tools for water quality mapping and land cover mapping essential for monitoring, modeling, and environmental change detection. Geographic Information System (GIS) can be a powerful tool for developing solutions for water resources problems in assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale (10,11). Therefore, the aim of this study was to determine the WQI of stream reaches exposed to point and non-point discharges of flow through trout farm and diffuse discharges of rural community and agricultural, then this river zoning by GIS.

Methods

Description of the watershed investigated

Moradbeik river drains a 30 km^2 catchment in south of Hamedan. The population relies on Moradbeik river as a source of domestic, industrial, and irrigation water; habitat for fish and other wildlife; and a place to recreate. The river also receives highly treated and untreated municipal and industrial wastewater from the urban population. The catchment is illustrated in (Table 1). The main river length is 18 km.

Procedure for watershed sampling

Collection vials, sample stabilization, and transportation to the laboratory as well as sample storage were done considering the recommendations of standard methods (12) and Environmental Protection Agency (EPA) (13). Samples were taken from at least 40 cm under the water surface and whenever it was possible, at the middle of the stream. Samples were never taken when it was raining, but only at least 72 h after the rain had stopped, so that the river had returned to its usual flow condition. Sampling for watersheds was carried out over 12 months, covering all stations. The samples were taken approximately every month and were transported to the laboratory for quantification of the other parameters after the determination of field parameters.

Sample collection and analysis

Temperature, pH (standard method 4500), and Dissolved Oxygen (DO) (standard method 4500) values of water samples were measured in the field using a thermometer and a portable pH meter (HACH, sension 1) and DO meter (HACH, 6), respectively. Samples for Biochemical Oxygen Demand (BOD) (standard method 5210) were collected in 250-ml-glass bottles which were closed under the water. Polythene bottles were soaked in 1.5 m nitric acid for 4 days and washed thoroughly with distilled and deionized water before use. Water samples were collected in polythene bottles. BOD was determined after incubation for 5 days in tightly stoppered bottles in the dark at 20 °C and determination of the oxygen consumed (12). The total suspended solids and total dissolved solids were separated by filtering the water through 0.45 mm paper filter and determined according to standard procedures (12). Conductivities were measured at 25 °C directly using a digital conductivity meter (HACH, session 5). Nitrate (NO_3^-) (standard method 4500) was determined by spectrophotometric method at 220 nm (UV-1700 Pharma Spect Shimadzo) Inorganic phosphates ($P\text{-}PO_4^{-3}$) (4500) were estimated by the phosphomolybdate method photometrically after conversion of orthophosphates by being digested with persulfate. Turbidity was quantified using

Table 1. Description of the sampling points

Point	Altitude (m)	Geographic coordinates
1	2080	34°44.820 48°30.261
2	1960	34°45.314 48°30.619
3	1940	34°45.593 48°30.666
4	1900	34°46.769 48°30.702
5	1778	34°48.981 48°31.116
6	1740	34°51.497 48°30.959

a turbidimetry HACH (2100N). Fecal Coliforms were assayed according to the membrane filter technique (colony/100 mL).

Water Quality Index (WQI) calculations

WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which summarizes different quality parameters. WQI is an index of water quality for a particular use. Mathematically, the index is an arithmetic weighing of normalized water quality measurements. The normalizations, as well as the weighings are different for different water uses (5). WQI used in this paper was calculated in three different ways and based on parameters: the first one produced a NFSWQI based on the parameters proposed by Brown and Forsythe (14) including: biochemical oxygen demand, dissolved oxygen, total fecal coliform, pH, temperature, total nitrate, total phosphorus, total solids, and turbidity. This WQI is calculated using the following equation:

$$WQI = \sum_{i=1}^{n} w_i q_i$$

where "WQI" is a number between 0 and 100 to indicate the water quality index; "q_i" is water quality score of parameter, "a" number between 0 and 100, obtained from the respective "curve average of quality" variation, as a function of concentration nor measurement; "n" the number of parameter used to calculated WQI, and "w_i" the weighing factor of parameter, a number between 0 and 1.

Results

Water quality of Moradbeik river was investigated for 12 months. The index was applied to six monitoring points in the aquatic bodies. Concentrations of these nine variables were normalized on a scale from 0 to 100 and translated into statements of water quality (excellent, good, regular, fair, and poor) (for example Figure 1A-B). The value of NSFWQI in 12 months is shown in (Figure 2).

The association between month and NSFWQI is not statistically significant (P>0.05; Figure 3). The association between station and NSFWQI was statistically significant (P<0.05; Figure 4).

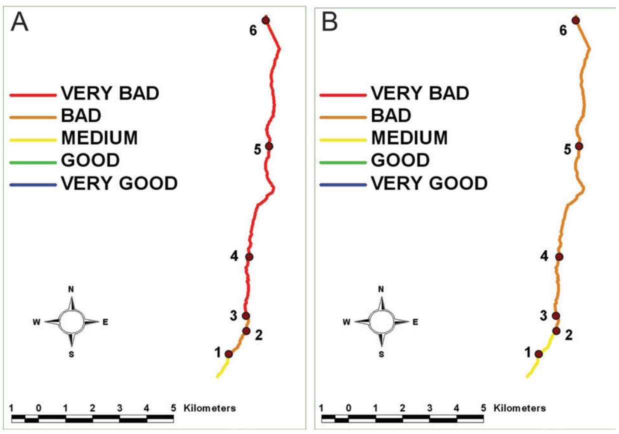

Figure 1. Water quality index map. A) October and November. B) September.

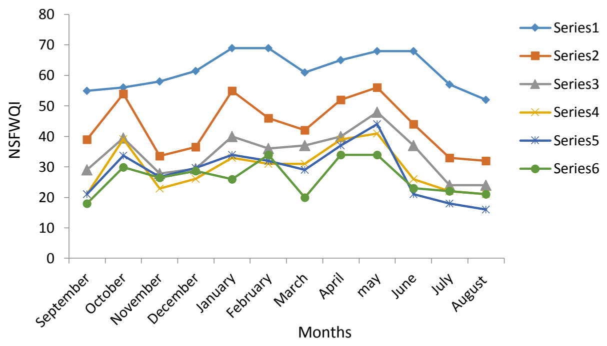

Figure 2. Value of NSFWQI in 12 months

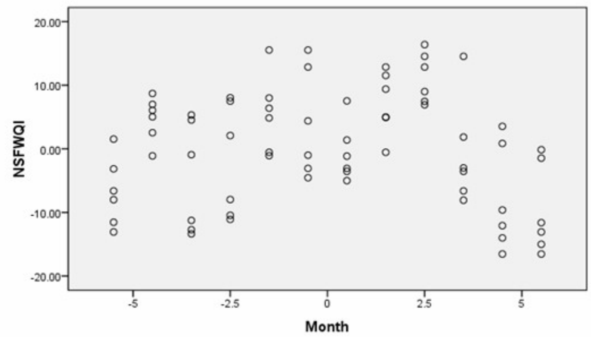

Figure 3. Association between month and NSFWQI

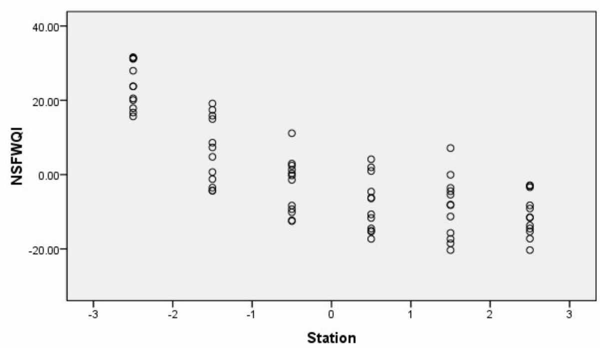

Figure 4. Association between stations and NSFWQI

Discussion

Gazzaz *et al* (15) surveyed the artificial neural network modeling of the water quality index for Kinta river (Malaysia) in 2012 using water quality variables as predictors. The result of a survey by Koçer and Sevgili (16) in 2014 showed that WQI_{min} calculated using NH^+_4-N and TON is a useful and easily applicable methodology in the assessment of the impacts of trout farm effluents on the stream water quality. Modified pollution indices were used to evaluate the pollution status in the middle section of the Lower Seyhan River Basin by employing a GIS software (ArcGIS 9.3) for data processing, estimations, and evaluations. Air Quality Index (AQI) and WQI were utilized to evaluate air and water pollution levels, respectively (12). A survey by Ma *et al* (17) in 2013 with subject of "a modified water quality index for intensive shrimp ponds of Litopenaeus vannamei" has shown modified WQI based on the varifactors was applied to evaluate the water quality in shrimp culture ponds. The result revealed that the overall water quality in the shrimp ponds was mainly excellent during the early period and deteriorated in the mid to late period. The average of NSFWQI was 61.62, which corresponds to "medium" quality water at sampling point 1 (16), the best station, and decreased to around 6.41 (bad quality) at sampling point 6. The demonstrated monitoring of Moradbeik watersheds was slightly affected by the section of the river within this town. The association between month and NSFWQI was not statistically significant ($P>0.05$; Figure 3). The association between station and NSFWQI was statistically significant ($P<0.05$; Figure 4). The results of this study are consistent with Gazzaz *et al*'s study. The WQI predictions of this model had a significant, positive, and very high correlation ($r= 0.977$, $P<0.01$) with the measured WQI values, implying that the model predictions explain around 95.4% of the variation in the measured WQI values (15). WQI_{min} calculation with NH_4^+-N, Total Organic Nitrogen (TON), soluble reactive phosphorus, and total organic phosphorus, which were selected using the principal component analysis findings meaningfully, classified the sampling points. Further reduction of parameters to NH_4^+-N and TON in WQI_{min} calculation achieved a similar successful classification of the sampling points (16). Sampling point 1 were more suitable than other sampling points for drinking uses. This station's water with pH adjustment and primary treatment can be used for drinking, but other stations are not potable and must be post treated. Results indicated that for the available data and time frame considered in the study, air and water qualities generally were in good conditions (low pollution), yet, precautions could still be taken for improvement (16,18). WQI evaluates water quality synthetically; furthermore, it reveals the outcome when some of the other variables deteriorate significantly. Thus, this study illustrates the necessity and usefulness of multivariate statistical techniques for interpreting large and complex data sets regarding water quality in shrimp culture pond. Furthermore, the evaluation results revealed that the modified WQI can be used as a tool for determining water quality. There is no index for significant statistical relationship between the months of the study sample ($P>0.05$).

Conclusion

Distribution of pollution, river pollution, and low rainfall in the months to months is more rain. Pollution of rivers in the rainy months also cannot generally undo. Based on physical, chemical, and biological agent monitoring and also with control of water quality indexes in these points, we observed that wastewater and other forms of pollution can arrive the river. Results also indicated the need for improvement of monitoring network for better assessment of the environmental quality in the whole basin (17). In general, GIS tools were very helpful in the development of the indices. There are many reasons for pollution levels in rivers, being more rural, urban, and industrial sewage discharge than the annual rainfall.

Acknowledgements

The authors are most grateful to the laboratory staff of the Department of Environmental Health Engineering, School of Public Health, Hamadan University of Medical Sciences, Iran, for their financial support and collaboration in this research.

Ethical issues

We certify that all data collected during the study is presented in this manuscript and no data from the study has been or will be published separately.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MTS, MHS, and AR conceived and designed the study. SHS and MHS performed the literature search and wrote the manuscript. All authors participated in the data acquisition, analysis and interpretation. All authors critically reviewed, refined and approved the manuscript.

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