The role of faecal coliforms in water quality assessment

Riđanović L.[1]; Terzić R.[2], Riđanović S.[1]

Received: November 2017 Accepted: September 2017

Abstract

The paper aims to evaluate the role of faecal coliforms in assessment of water quality. The study was conducted on the Neretva River in Bosnia and Herzegovina. The sampling was performed bimonthly, over 12 months at seven selected sites. APHA (1995) methods were used. The raw data of temperature, pH, conductivity, oxygen saturation, nitrogen, total phosphorus, and faecal coliforms were transformed into unitless subindices on a scale of 0 to 100 (Ridanovic *et al*., 2012). NWQI was calculated as a harmonic mean of subindices. Application of NWQI as indicator of water quality was demonstrated through spatial analysis of water quality. Results show a significant decrease (>50%) of water quality. Linear regression was used to assess which parameter has the greatest influence on NWQI value. Results suggest that all tested parametres are strongly connected to NWQI (nitrogen, R^2=0.7455422), (total phosphorus, R^2=0.887803), (oxygen saturation R^2 =0.696964), (pH, R^2=0.595705). However, NWQI value was the most significantly affected by faecal coliforms (R^2=0.9788). Subindex values for conductivity and temperature were 100, hence their connection to NWQI cannot be analysed by linear regression. Results show how much NWQI changes with a change in one or more subindices, as it assumes a causal relationship between them.

Keywords: Water quality, Faecal coliforms, monitoring, Neretva Water Quality Index (NWQI)

1-Department of Biology, Faculty of Education, Džemal Bijedić University of Mostar
2-Faculty of Science, University of Tuzla
*Corresponding author's Email: lejla.ridjanovic@unmo.ba

Introduction

Global concern about scarcity of freshwater supplies has placed water quality monitoring and associated methodology as some of the most important ecological issues of today. It is often essential to rapidly evaluate water quality on site. There is an unlimited number of parametres and combinations of parametres which can and have been used to assess water quality. However analysis of parametres based on common characteristic provides only limited information on the overall water quality (Pesce and Wunderlin, 2000). These obstacles have been addressed by development of Water Quality Indeces (WQI), which have been described in litererature in 1965 (Horton, 1965). General WQI was developed by Brown *et al.*, (1970). The data obtained by WQI approach are important for development of management strategies for preserving and improving the quality of surface waters (Cude, 2001). Regular monitoring of water quality detects changes (good and bad) and suggests remediation measures. Monitoring data are necessary to identify the problems and focus attention where it is needed the most. The water can be classified and its potential usage determined.

There is no single WQI that is accepted globally. The majority of described indices are purpose specific and assess the water with a particular view. Some WQI are straightforward and easy to calculate, others use aggregation of many water quality parametres. Most WQI rely on standardisation of analytical data of each parametre according to the set regulatory limits. Assessment of WQI usually requires the measurement of many physical and chemical parametres. The challenge for developing countries is to create a cost-effective strategy for controlling pollution as associated analytical costs can be a limiting factor for the assessment of water quality (Ongley, 1998; Ongley and Booty, 1999). In such a situation, the assessment of WQI using just a few simple parameters, is a great asset.

Development and application of the *Neretva Water Quality Index* (NWQI) in evaluating water quality was described by Ridanovic *et al*., (2012) whereby the grouping of certain parameters produces a single numeral which determines water quality. The Neretva Water Quality Index is an instrument which determines water quality and classifies the water into a corresponding quality class. It is based on grouping of representative parametres from different categories of impairment of surface waters. Using NWQI, evaluation of water quality is not based solely on analytical values of individual parameters, but on the joint effect of several measured parameters on a single value of water quality. NWQI allows the most impaired variable to make the largest impact on the value of the index, and takes into account the fact that different variables will exert varying impacts on the overall water quality at a different place and time.

The present study aims to evaluate the impact of faecal coliforms on the value of the Neretva Water Quality Index (NWQI). The value of faecal coliforms concentration in a water sample is vital for the assessment of bacteriological safety of water.

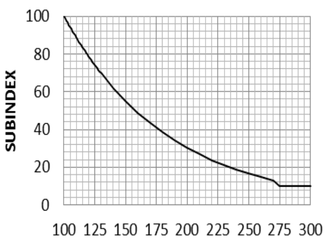
Materials and methods

The study was conducted in the middle-catchments area of the Neretva River in Southern Bosnia and Herzegovina. The study area was approximatelly 25 km long, located within the Greater City of Mostar. Seven sampling sites were selected: S1-Bijelo polje; S2-Carina; S3-Centar; S4-Stari grad; S5-Mahala; S6-Bišće polje; S7-Buna. The average depth of water was nine metres. In this part of the Neretva River basin submediterranean climate prevails. The sampling was conducted at biomonthly intervals during a 12-month monitoring program. The water sampling and laboratory analyses were performed according to the methods described in Standard Methods for the Examination of Water and Wastewater (APHA) (1995).

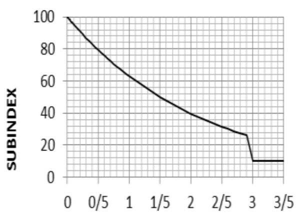
In order to calculate NWQI, the raw data of temperature, pH, conductivity, oxygen levels, nitrogen (ammonia+nitrate), total phosphorus, and faecal coliforms are transformed into unitless subindices on a scale of 0 to 100 according to methodology described in Ridanovic *et al*. (2012). The composite NWQI was then calculated as a harmonic mean value of subindices of selected parameters. Subindex of each parametre can be read off the specially constructed subindex curves (Graphs 1-5). The curves have been constructed on the basis of formulas for transformation of subindeces that had been, by using non-linear regression, originally set by Dunnett (1980) and reworked by Cude (2001).

Curves for determination of subindex values

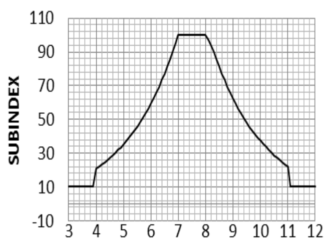
Grahs



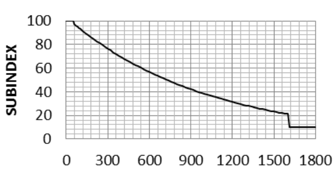
Graph 1. OXYGEN SATURATION (%)



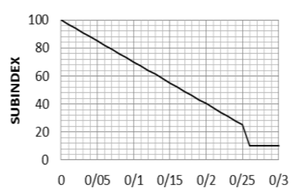
Graph 2. NITROGEN (ammonia + nitrate) (mg/l)



Graph 3. pH



Graph 4. FAECAL COLIFORMS (cfu/100 ml)



Graph 5. TOTAL PHOSPHORUS (mg/l)

Results and Discussion

The analytical values of selected parametres used to determine subindices and composite NWQI are presented in Tables 1 and 2. These parametres are clearly linked to the quality of water and are the most significant indicators of specific environmental conditions that prevail in this ecosystem. They represent seven different categories of waterway impairment and are also good indicators of specific issues relevant at the global level (eutrophication, nutrient pollution, acidification, siltation, climate change). NWQI was simply calculated as a harmonic mean of all seven subindices. The harmonic mean is used to determine the average ratio of the parametres tested.

Application of NWQI as an indicator of water quality and pollution has been demonstrated through analysis of spatial variations of water quality.

Table 1: Analytical values of tested parametres.

Parametre	Sampling site						
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
T (ºC)	10,1	10,1	10,6	10,6	10,7	10,6	10,8
pH	7,3	7,3	7,3	7,2	7,2	7,2	7,1
EP ($\mu Scm^{-1)}$	282	295	294	297	296	296	309
O_2 (mg/l)	12,6	12,7	12,7	12,5	12,3	12,5	12,3
O_2 %	112,3	113,8	114,6	111,9	110,9	111,9	111,5
NH_4^+ (mg/l)	0,02	0,02	0,03	0,01	0,03	0,02	0,04
NO_3^- (mg/l)	0,43	0,45	0,46	0,45	0,46	0,46	0,52
P (mg/l)	0,00	0,00	0,01	0,01	0,14	0,16	0,16
FC (br/100ml)	30	140	700	1100	960	1200	1000

Table 2: Subindeces of water quality.

SITE	T (ºC)	pH	O_2 %	N	P	FC	EP	NWQI
S-1	100	100	86,3	81,3	100	98	100	**94,5**
S-2	100	100	84,7	80,5	100	59,7	100	**86,4**
S-3	100	100	83,9	79,8	97	28,4	100	**69,9**
S-4	100	100	86,7	80,9	97	10	100	**42,6**
S-5	100	100	87,7	79,8	58	10	100	**40,9**
S-6	100	100	86,7	80,2	52	10	100	**40,4**
S-7	100	100	87,12	77,3	52	10	100	**40,3**

The water quality is considerably higher at Bijelo polje (S-1) compared to other sites. There is a degradation of water quality along the longitudinal profile. Results show significant decrease (>50%) of water quality in urban areas. NWQI for S-1 (Bijelo polje) was 94.5. At S-2 (Carina) there is a reduction of quality for 8.1 units of water quality. This trend of water quality degradation continues across the sampling sites. The maximal decrease of WQI values is noted between S-3 (Centar) and S-4 (Stari grad), associated with wastewater effluents. Throughout the researched area of the waterway, 25 km long, there was a fall of over 50 water quality units. Within the inner city area (S-2 to S-6) the river has lost 46 units of water quality. NWQI value looses less than one water quality unit between S-4 (Stari grad) and S-5 (Mahala). Application of NWQI allowed classification of water quality according to a classification scale by Cude (2001) (Table 3).

Table 3: Classification scale for NWQI.

NWQI	Water quality
90-100	Excellent
85-89	Good
80-84	Adequate
60-79	Poor
10-59	Very poor

The water quality is classified as "very poor" at four of seven sampling sites (Table 4).

Table 4: Water quality at sampling sites

Site	Water Quality	NWQI
S-1	Excellent	94,5
S-2	Good	86,4
S-3	Poor	69,9
S-4	Very poor	42,6
S-5	Very poor	40,9
S-6	Very poor	40,4
S-7	Very poor	40,3

The NWQI value does not improve at S-7 (Buna) located 11 km downstream from the centre of the city (Fig. 1).

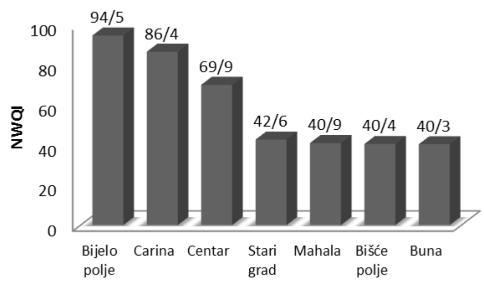


Figure 1: Values of NWQI at sampling sites.

The linear regression was used to assess which parameter (subindex) has the greatest influence on the value of the composite NWQI. This analysis shows the extent to which the value of a subindex can predict the value of NWQI. It also shows whether they are codependent, and if there is a relationship which parameter is the most important and which predicts the NWQI value most reliably and accurately. The maximum values are -1 or +1 (Petz, 2007). Results suggest that all tested parametres are strongly connected to the NWQI: (nitrogen, R^2=0.7455422), (total phosphorus, R^2=0.887803), (oxygen saturation R^2=0.696964), (pH, R^2=0.595705). However, the NWQI value is the most significantly affected by faecal coliform counts, as it is the most impaired variable (R^2=0.9788). The regression analysis helps us to understand how much the NWQI as a dependent variable changes with a change in one or more subindices as independent variables, as it assumes a causal relationship between one or more subindices and NWQI. It also identifies the strength of the effect that a subindex value has on NWQI, and predicts trends and future values. Conductivity and temperature were not included in analysis, because all subindex values are 100, hence their connection with NWQI cannot be analysed by linear regression.

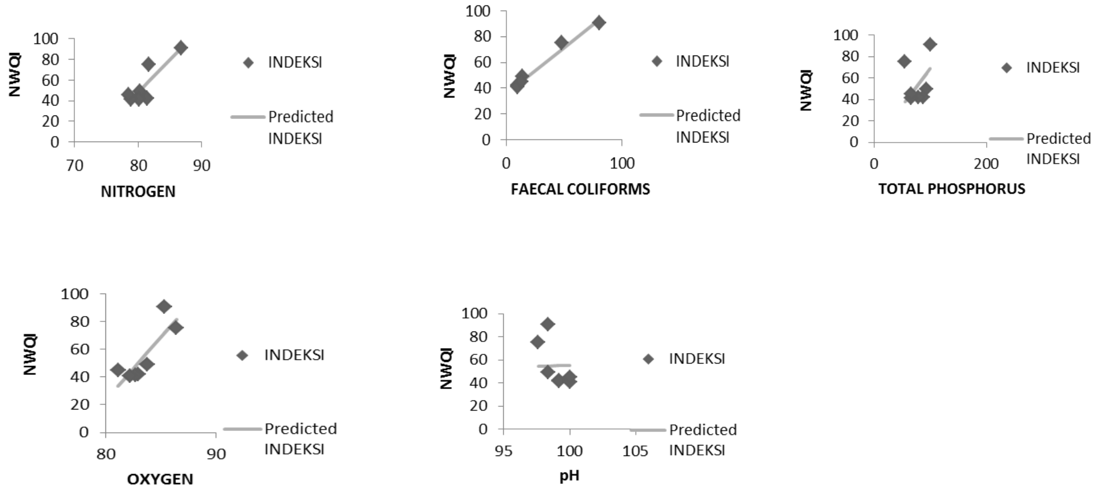


Figure 2: Linear regression of NWQI with subindices of tested parametres – line fit plots.

Conclusion

Neretva Water Quality Index (NWQI) is a useful tool that determines quality and classifies the water into a corresponding water quality class. It is based on the grouping of parameters representing different categories of waterway impairment. Using NWQI, assessment of water quality is not based solely on the analytical values of the parameters, but on values of multiple parameters acting as a whole. Interpretation of the data is easy, as it integrates a series of complex data into a single figure that describes the overall state of water quality, and allows monitoring of changes in water quality as well as identifying specific parameters responsible for the degradation of quality. It allows the most impaired variable to make the greatest impact on the index, and takes into account the fact that different parametres have different significance for the overall quality of water in different places at different times. NWQI is designed for everyday use and a general assessment of the water in a simple and quick way, reliably identifying specific categories of degradation of quality. It reduces the need for frequent monitoring that entails extensive, time consuming and costly analyses. For developing countries with limited budgets, this is of great importance.

References:

American Public Health Association (1995). Water Environment Federation. Joint Publication. Standard methods for the examination of water and wastewater. 19th ed. Washington, D.C., pp. 53-65

Brown, R.M., McClelland, N.I., Deininger, R.A., Tozer, R.G., 1970. A water quality index: Do we dare? *Water and Sewage Works*, 117, 339-343.

Cude, C.G., 2001. Oregon water quality index: A tool for evaluating water quality management effectiveness. *Journal of American Water Resources Association*, 37(1), 125-137.

Dunnette, D.A., 1980. Oregon Water Quality Index Staff Manual. Oregon Department of Environmental Quality, Portland, Oregon. 37 (3), 300-306.

Horton, R.K., 1965. An index-number system for rating water quality. *Journal of Water Pollution Control Federation, 37* (**3**), 300-306.

Ongley, E., 1998. Modernization of water quality programs in developing countries: Issues of relevancy and cost efficiency. *Water Quality Int.*, Sep/Oct, 37-42 pp.

Ongley, E.D. and Booty, W.G., 1999. Pollution remediation planning in developing countries: Conventional modelling versus knowledge-based prediction. *Water International*, 24, 31-38.

Pesce, S.F. and Wunderlin, D.A., 2000. Use of water quality indices to verify the impact of Cordoba city (Argentina) on Suquya river. *Water Research*, 34(**11**), 2915-2926.

Petz, B., 2007. Basic statistical methods. VI Ed. The University of Zagreb, Naklada Slap, Croatia**.** pp. 211-214.

Riđanović L., Đonlagić M., Riđanović S., 2012. Evaluation of Neretva River Water Quality Using Neretva Water Quality Index (NWQI). BALWOIS 2012, 5th International Conference on Water, Climate and Environment, Ohrid, Macedonia. 2012-0478.