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Applying of water quality indices methods for assessment of 9-Nissan Water Treatment Plant

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Abstract

In this research different methods for measuring water quality indices were conducted to investigate the performance of the newly designed, constructed and operated 9-Nissan water treatment plant, Iraq. Data gathering and implementation took place throughout winter and summer. Water samples were taken periodically, according to the standard method, the research was carried out by collecting different random samples for eight months (Jun. 2015–Jan. 2016) and measuring (turbidity, total hardness, pH, total dissolved solids, suspended solids, Cl^-, Mg^{2+}, Fe^{2+},NO_3^-, NH_3^+) for each sample. Five different approaches and methodologies of calculating the water index were applied. The results revealed that the Water Quality Indices varied from 70.55 to 88.24, when applying Canadian Council of Ministers of the Environment Water Quality Index (*CCMEWQI*) and British Columbia water quality index (*BCWQI*) geometric weighted mean respectively. All the results, from the five approaches indicated good water quality, multiple regression analyses were conducted for turbidity, total hardness and suspended solids, they found that these parameters are strongly related to each other and to other parameters.

Key words: *nitrate, pH, suspended solids, water quality index, water treatment plant*

INTRODUCTION

An important issue concerning human health is the accessibility to the clean water, which is absolutely essential for to ensure healthy living [MANDALAM *et al.* 2009]. Recently, there has been a huge shortage of fresh water supplies in many countries (including Iraq) due to population increase, unplanned urbanization, industrialization, and agricultural activities, that, in turn, has led to aggressive consumption of surface water supplies [BHARTI, KATYAL 2011].

Typically, water quality from any treatment plant is determined by comparing the physical and chemical properties of a water sample(s) (from the inlet and the outlet to the treatment plant) with water quality guidelines or standards [HARKINS 1994]. Drinking water quality guidelines and/or standards were introduced to ensure the provision of clean, healthy and safe water for human consumption, hence, protecting human health. These are usually based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms.

One method to assess water quality status and characteristics is by using water quality indices [SALIM *et al.* 2009]. It is a technique that provides a meaningful insight into water quality data which is both useful to technical (as improving the condition of operations, upgrading the treatment units of the treatment plants… etc.), and non-technical personnel to aid their decision making [REEN *et al.* 1980].

MATERIAL AND METHODS

2.1. WATER QUALITY INDEX (*WQI*)

Water quality was classified by HORTON [1965]. Then later, BROWN [1970] introduced a general water quality index (*WQI*). STEINHART *et al.* [1982] applied the quality index principle to determine the need for technical information on the water quality of Great Lakes. In early 1996, *WQI* was introduced in Canada by the water quality guidelines task group of Canadian Council of Ministers of the Environment (CCME) [HÈBERT 1996]. A series of task groups worldwide started to form their own (*WQI*) strategy i.e.: In the U.S.A. National Sanitation Foundation water quality index (*NSFWQI*), Florida Stream water quality index (*FWQI*), British Columbia water quality index (*BCWQI*), and the Oregon water quality index (*OWQI*).

WQI is an arithmetical approach and tool used to switch large amounts of water quality data into a single cumulative number. It is considered as an algorithm that indicates a measure of the qualitative status of the water. The final result can be a simple combination of numeric variables. The criterion of *WQI*s is based on the comparison of the water quality parameter(s) with representative, respective and reliable regulatory (international (or/and), regional, (or/and) national) standards [KHAN *et al.* 2003]. The *WQI*'s are not substituting the need for a detailed analysis of environmental monitoring for the sustainability of the water quality. The benefits that result from the implementation of such tool include the ability to represent measurements of a wide spectrum of variables in a single number, the capability to gather various measurements with different measurement units in a single unit [ZANDBERGEN, HALL 1998].

There are different classifications and categories for the *WQI* that reflects the state of the water from the pollution strength perspective, according to the CCME and *NSF* [NAWAR 2008]. There are different categorizations related to the index values. Classified as: excellent (95–100), no health impact; Good (80–94), may cause minor health impact; Fair index (65–79), occasionally cause an impact to health; Marginal index values (45–64), frequently cause a health impact; Poor (0–44), almost cause health impact [DEBELS *et al.* 2005]. This refers to the most common *WQI* categories.

There are a number of formulas used for the determination of the *WQI* .

Cumulative formulation. This formula was used by [HORTON 1965], and it was introduced as a basis to develop the index. The formula is expressed as:

$$WQI = \frac{\sum_{i=1}^{n} C_i W_i}{\sum_{i=1}^{n} W_i} \tag{1}$$

Where: C_i = the rating for the i^{th} determinant; n = number of determinants; W_i = the weighting for the i^{th} determinant.

Arithmetic weighted formula. This formula was developed by BROWN [1970], and expressed as:

$$WQI = \sum_{i=1}^{n} Q_i W_i \tag{2}$$

Where: Q_i = represents the rating for the i^{th} determinant, this value varies from 0 to 100; W_i = represents the weight for the i^{th} determinant and this value varies from 0 to 1 and $\Sigma W_i = 1$; n = number of determinants.

This formula was created by rigorously selecting parameters, developing a common scale and assigning weights to the parameters [AL-SAQAR, ABDUL-KHALIK 2009]. National Sanitation Foundation (NSF) support this index, as such it is also called *NSFWQI*. The formula was developed to attribute values for variation in the level of water quality caused by different levels of each of the selected parameters [HOUSE 1989].

Geometric weighted mean. BROWN [1970] used the multiplicative weighted formula depending on the arithmetic weighted formula using the same symbols ZANDBERGEN, HALL [1998]. The formula is expressed as:

$$WQI = \sum_{i=1}^{n} Q_i W_i \tag{3}$$

Modified arithmetic weighted formula. This is a modified arithmetic weighted formula [HARKINS 1974]. The formula is expressed as:

$$WQI = \frac{1}{100} \sum_{i=1}^{n} (Q_i W_i)^2 \tag{4}$$

British Columbia water quality index (*BCWQI*). This was developed by the Canadian Ministry of Environment as an increasing index. For water quality evaluation, where water quality parameters are measured and their violation is determined by comparison with a predefined limit. The *BCWQI* makes possible the classification on the basis of all existing measurement parameters. The formula is expressed as:

$$BCWQI = 100 - \left[\frac{({F_1}^2 + {F_2}^2)}{1.453}\right]^{0.5} \tag{5}$$

Where: F_1 (scope) = number of the non-succeeded variables to the total number of the variables; F_2 (frequency) = number of the unsuccessful tests to the total number of tests.

$$F_1 = \frac{NF}{TNV} 100 \tag{6}$$

$$F_2 = \frac{NFT}{TNT} 100 \tag{7}$$

Where: *NF* = number of the failed variables, *TNV* = total number of variables, *NFT* = number of the failed test; *TNT* = total number of the tests.

In the *BCWQI* formula 1.453 is the constant used to give confidence to the scale index number from 0 to 100. The degree of the confidence in the *BCWQI* depends on the repeated sampling procedure [POONAM 2013].

Canadian Council of Ministers of the Environment (CCME) water quality index (*CCMEWQI*). This approach examines multi-variable water quality test data against specific water quality benchmarks. The CCME *WQI* model consists of three measured variables from selected water quality concept (scope, frequency, amplitude) [BASIM 2006]. These three measures of variables are combined to result in a range between 0–100 in which it will reflect the whole water quality. The formula is expressed as:

$$CCMEWQI = 100 - \left[\frac{({F_1}^2 + {F_2}^2 + {F_3}^2)}{1.732}\right]^{0.5} \tag{8}$$

$$F_1 = (nvn/tnv)100 \tag{9}$$

Where: *nvn* = number of the variables whose objectives are not met with the guide line, *tnv* = total number of variables.

$$F_2 = (ntn\ /tnt)100 \tag{10}$$

Where: *ntn* = number of tests whose objectives are not met the guide line, *tnt* = total number of tests.

F_3 represents amplitude: the range to which the unsuccessful tests are above the guideline
(a) range/excursion = (the unsuccessful test value/the guideline value) – 1
(b) (sum of excursions) = Σ no. of excursions/no. of tests
F_3 = (sum of excursions/0.01 normalized sum of excursions) + 0.01
Explanation: excursion 1 = (failed test values/objectives) when the test value must not exceed the objective; excursion 2 = (objectives/failed test values) when the test value must not fall below the objective.

The constant 1.732, is a scaling factor = √3 to ensure the index be from 0 to 100 [AL-OBAIDY *et al.* 2015].

In order to calculate the *WQI*, the Iraqi drinking water standard values corresponding to the measured parameters were used, as shown in Table 1.

Table 1. Iraqi drinking water standards

Parameter	Measurement unit	Iraqi standards values
Turbidity	NTU	5
TH	$mg \cdot dm^{-3}$	500
pH	–	7.5
TDS	$mg \cdot dm^{-3}$	350
TSS	$mg \cdot dm^{-3}$	120
Cl^-	$mg \cdot dm^{-3}$	250
Mg^{2+}	$mg \cdot dm^{-3}$	100
Fe^{2+}	$mg \cdot dm^{-3}$	0.35
NO_3^-	$mg \cdot dm^{-3}$	55
NH_3^+	$mg \cdot dm^{-3}$	0.4

Explanations: *TH* = total hardness, *TDS* = total dissolved solids, *TSS* = total suspended solids.
Source: Iraqi Drinking Water Quality Code number [2007].

9-NISSAN UNIT WATER TREATMENT PLANT

This water treatment plant, located in 9-Nissan quarter eastern side of the army canal in Baghdad, with the geographical coordinates 33.334986, 44.491707. It was constructed in 2012 in order to cover the needs and the water demands to around 400,000 capita in this area. The nominal capacity of the plant is 250 $m^3 \cdot h^{-1}$, and its raw water source is from the two direct boosting pump stations from the Tigris River (8 km away from the plant). The plant consists of eight steel sedimentation tanks, eight rapid sand filters tanks with a chlorine disinfection unit and a sludge disposal pipe channel.

Experimental work and procedures. In order to have representative data from the plant, daily tests and records for the raw water that entered into the plant and the treated water from the plant were conducted. Different water environmental and health parameters were measured turbidity, total hardness, total dissolved solids, suspended solids, pH, Cl^-, Mg^{2+}, Fe^{2+}, Ca^{2+}, NO_3^-, NH_3^+. Two samples were taken every day (during operational hours) of the raw water and the treated (produced) water from the treatment plant, and all the previous parameters were measured for the two samples. The measurements and tests procedures were conducted from Jun 2015 to Jan 2016 in order to cover the variation in the weather conditions that may have an effect on either the raw water and the treated water quality.

RESULTS

The average monthly results for the whole period of the research for the treated water properties produced the treatment plant were tabulated in Table 2.

By applying the five previously mentioned methodologies respectively for calculating *WQI* for the treated water, the results were tabulated in Tables 3–7 respectively.

Multiple regression analysis. This approach and technique were introduced to test the most effective (dominant) water quality parameter that had influenced the whole water quality and it was as follows:
Turbidity = 0.493 – 0.527 *TSS* + 0.362 Fe^{+2} + 0.255 *TH* + 0.422 Cl^- – 0.256 NO_2^- + 0.241 Mg^{2+} + 0.171 turbidity + 0.007 NH_3^+
TH = 0.031 – 0.851 *TSS* – 0.33 *TH* + 0.37 NO_2^- + 0.222 Mg^{+2} – 0.0075 pH
Suspended solids = –0.074 pH + 0.063 turbidity – 0.064 NO_3^- + 0.022 Cl^- – 0.0073 *TH*

Table 2. Average monthly tests results for the treated water produced from the plant

Parameter	Measurement unit	Value in test							
		Jun 2015	Jul 2015	Aug 2015	Sept 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016
Turbidity	NTU	16	27	13	7	17	22	15	27
TH	$mg \cdot dm^{-3}$ as $CaCO_3$	103	210	144	182	132	1211	162	122
pH	–	7.2	7.3	8.01	7.4	7.4	7.6	8.02	8.00
TDS	$mg \cdot dm^{-3}$	129	114	132	164	154	211	200	165
TSS	$mg \cdot dm^{-3}$	223	187	169	213	201	223	285	154
Cl^-	$mg \cdot dm^{-3}$ as chloride	22	52	25	31	41	32	43	29
Mg^{2+}	$mg \cdot dm^{-3}$	43	51	34	41	45	50	33	38
Fe^{2+}	$mg \cdot dm^{-3}$	0.87	0.30	0.66	0.33	0.29	0.61	0.19	0.18
NO_3^-	$mg \cdot dm^{-3}$ as nitrate	0.12	0.31	0.22	0.13	0.21	0.11	0.18	0.18
NH_3^+	$mg \cdot dm^{-3}$	0.03	0.02	0.10	0.12	0.04	0.02	0.01	0.10

Explanations as in Tab. 1.
Source: own study.

Table 3. The water quality index (*WQI*) according to the cumulative formulation

Parameter	Measurement unit	Q_i	S_i	W_i	q_i	$W_i q_i$	*WQI*
Turbidity	NTU	18	5	0.2	360	72	82.48
TH	mg·dm^{-3}	136	500	0.002	27.2	0.054	
pH	–	7.6	7.5	0.133	101.3	13.4	
TDS	mg·dm^{-3}	159	350	0.0028	45.42	0.127	
TSS	mg·dm^{-3}	207	120	0.0083	172.5	0.69	
Cl^-	mg·dm^{-3}	34	250	0.004	13.6	0.054	
Mg^{2+}	mg·dm^{-3}	42	100	0.01	42	0.42	
Fe^{2+}	mg·dm^{-3}	0.42	0.35	2.85	120	342	
NO_3^-	mg·dm^{-3}	0.18	55	0.018	0.32	0.00576	
NH_3^+	mg·dm^{-3}	0.07	0.4	2.5	17.5	43.75	

Explanations: Q_i = average value from Jun 2015 to Jan 2016, $W_i = 1/S_i$, $q_i = 100(\text{parameter}/S_i)$, $WQI = \Sigma(W_i \cdot q_i)/\Sigma W_i$; other symbols as in Tab. 1.
Source: own study.

Table 4. The water quality index (*WQI*) according to the arithmetic weighted formula

Parameters	Measurement unit	W_i^*	Q_i	$W_i^* Q_i$	*WQI*
Turbidity	NTU	0.390	18	7.02	86.51
TH	mg·dm^{-3}	0.063	136	8.56	
pH	–	0.219	7.6	1.662	
TDS	mg·dm^{-3}	0.047	159	7.47	
TSS	mg·dm^{-3}	0.053	207	10.97	
Cl^-	mg·dm^{-3}	0.740	34	25.1	
Mg^{2+}	mg·dm^{-3}	0.610	42	25.6	
Fe^{2+}	mg·dm^{-3}	0.740	0.42	0.319	
NO_3^-	mg·dm^{-3}	0.412	0.18	0.07	
NH_3^+	mg·dm^{-3}	0.044	0.07	0.0176	

Explanation: W_i^* = parameters weight value acc. to YOGENDRA and PUTTAIAH [2008], Q_i = as in Tab. 3; other symbols as in Tab. 1.
Source: own study.

Table 5. The water quality index (*WQI*) according to the geometric weighted mean

Parameter	Measurement unit	W_i^*	Q_i	$W_i^* Q_i$	∏	*WQI*
Turbidity	NTU	0.390	18	7.02	1.02	88.24
TH	mg·dm^{-3}	0.063	136	8.56		
pH	–	0.219	7.6	1.662		
TDS	mg·dm^{-3}	0.047	159	7.47		
TSS	mg·dm^{-3}	0.053	207	10.97		
Cl^-	mg·dm^{-3}	0.740	34	25.1		
Mg^{2+}	mg·dm^{-3}	0.610	42	25.6		
Fe^{2+}	mg·dm^{-3}	0.740	0.42	0.319		
NO_3^-	mg·dm^{-3}	0.412	0.18	0.07		
NH_3^+	mg·dm^{-3}	0.044	0.4	0.0176		

Explanations: W_i^* as in Tab. 4, Q_i = as in tab. 3, other symbols as in Tab. 1.
Source: own study.

Table 6. The water quality index according to the British Columbia (*BCWQI*)

Parameter	Measurement unit	F_1	F_2	*BCWQI*
Turbidity	NTU	3	2	79.93
TH	mg·dm^{-3}		3	
pH	–		1	
TDS	mg·dm^{-3}		2	
TSS	mg·dm^{-3}		2	
Cl^-	mg·dm^{-3}		3	
Mg^{2+}	mg·dm^{-3}		1	
Fe^{2+}	mg·dm^{-3}		2	
NO_3^-	mg·dm^{-3}		3	
NH_3^+	mg·dm^{-3}		4	

Explanations: F_1 = as in Eq. (9), F_2 = as in Eq. (10), other symbols as in Tab. 1.
Source: own study.

Table 7. The water quality index according to Canadian Council of Ministers of the Environment (*CCMEWQI*)

Parameter	Measurement unit	F_1	F_2	Excursion 1	Excursion 2	*NSE*	F_3	*CCMEWQI*
Turbidity	NTU	3	2	6.535	326.3	0.832	45.4	70.55
TH	mg·dm^{-3}		3					
pH	–		1					
TDS	mg·dm^{-3}		2					
TSS	mg·dm^{-3}		2					
Cl^-	mg·dm^{-3}		3					
Mg^{2+}	mg·dm^{-3}		1					
Fe^{2+}	mg·dm^{-3}		2					
NO_3^-	mg·dm^{-3}		3					
NH_3^+	mg·dm^{-3}		4					

Explanations: F_1 = as in Eq. (9), F_2 = as in Eq. (10), excursion 1 = (failed test values/objectives) when the test value must not exceed the objective, excursion 2 = (objectives/failed test values) when the test value must not fall below the objective; *NSE* = Nash–Sutclife efficiency, other symbols as in Tab. 1.
Source: own study.

DISCUSSION

From Table 2 it is clear that the variation of the indicated parameters was due to many different factors such as season, agricultural activities, etc., for example, the values of the turbidity increased during the rainy season (winter in Iraq Nov–Jan) adding an extra load of the turbidity to both the Tigris and the Euphrates Rivers. The results correlate with [AL-OBAIDY *et al*. 2015], that in turn increases the value of this parameter in both influent and effluent, although, a high value of turbidity recorded in the dry season (summer Apr.–Sept.), this may be considered as an anomaly or a misreported value. The same scenario is also related to both TH, suspended solids, Cl^- and Mg^{2+} which increased their discharge to the Tigris River in Baghdad within the winter season due to the wastewater discharged from the textile, rugs and carpets manufacturers located close to the bank of the Tigris River whose activities increases during the winter. While for the NO_3^- the increases in rate due to the excessive usage of fertilizers in the wide agricultural areas located on the Tigris River (northern Baghdad) that in turn adds an extra load to the treatment plants. These results are seen to correlate with those of [AL-SAQAR, ABDUL-KHALIK 2009].

For the multiple regression analysis, it is found that the formulas for the TH, suspended solid and turbidity values are related to Fe^{2+}, Cl^{-}, nitrate and Mg^{2+} (in addition to the interrelation to each other) with a range of applicability being within the average values of these parameters that measured for the plant during the research period.

As the water quality indices varied from 70.55 to 88.24 (according to the different approaches used and the related assumptions and concept of each approach method), the water quality was considered to be ranged from fair to good. And according to the Iraqi standards such quality of water can be used with the minor restriction of the usage for the infants and elders.

Although, the 9-Nissan water treatment plant is newly constructed, the quality of the produced tap water is of fair–good quality, and that is beyond the expectation from a newly constructed project. As with newly created plants there often comes a lack of experience in the operation of the project from the operator. In addition, the wide variation and deterioration in the Tigris River due to the Turkish dams on both Tigris and Euphrates Rivers, also reduces the water quality, with deterioration being recorded by the Ministry of Water Resources.

CONCLUSIONS

1. According to the results, the water quality index (*WQI*) for 9-Nissan water treatment plant can be categorized in the range of fair to good.

2. The good quality ranks are due to the cumulative, arithmetic mean and geometric mean approach for the *WQI*, this approach depends on the statistical techniques rather than justification for such increasing or decreasing in the *WQI* values, that is the reason for the *WQI* considering these three previous approaches to have approximately the close values.

3. For both British Columbia water quality index (*BCWQI*) and Canadian Council of Ministers of the Environment (*CCMEWQI*) approach, it is clear that a noticeable reduction in the *WQI* as these two approaches have a number of assumptions and physical engineering concepts in addition to the statistical tools for the determination of the *WQI*, that still cannot be covered by the parameters measured in the 9-Nissan treatment plant.

4. The multiple regression analysis reveals a strong dependency of the turbidity rather than other parameters on the value of the *WQI*.

REFRENCES

AL-OBAIDY A.H.M.J., Al-JANABI Z.Z., SHAKIR E. 2015. Assessment of water quality of Tigris River within Baghdad City. Mesopotamia Environmental Journal. Vol. 1. No. 3 p. 90–98.

AL-SAQAR A., ABDUL-KHALIK M. 2009. Management of water quality index for eastern-canal water treatment plant in Baghdad City. Journal of Engineering. Vol. 15. Iss. 2 p. 3606–3619.

BASIM H. 2006. Water quality index for the Shantia area on the Tigris River. Journal of Engineering. Vol. 12. Iss. 6 p. 764–773.

BHARTI N., KATYAL D. 2011. Water quality indices used for surface water vulnerability assessment. International Journal of Environmental Sciences. Vol. 2. No. 1 p. 154–173.

BHATIA S.C. 2013. Environmental pollution and control in chemical process industries. Delhi. KHANNA Publ. ISBN 81-7409-106-8 pp. 1273.

BROWN R. 1970. Water quality index– Do we dare? Water and Seweage Works. October p. 339–343.

DEBELS P., FIGUEROA R., URRUTIA R., BARRA R., NIELL X. 2005. Evaluation of water quality in the Chillán River (Central Chile) using physicochemical parameters and a modified water quality index. Environmental Monitoring and Assessment. Vol. 110. No. 3 p. 301–322. DOI 10.1007/s10661-005-8064-1.

HARKINS R.D. 1974. An objective water quality index. Journal (Water Pollution Control Federation). Vol. 34. Iss. 6 p. 70–72.

HÈBERT S. 1996. Développement d'un indice de la qualité bactériologique et physico-chimique de l'eau pour les rivières du Québec [Development of an index of the bacteriological and physicochemical quality of water for the rivers of Québec]. Québec, ministère de l'Environnement et de la Faune, Direction des écosystèmes aquatiques, envirodoq no EN/970102 pp. 20, 4 annexes.

HORTON R.K. 1965. An index number system for rating water quality. Journal (Water Pollution Control Federation). Vol. 37. No. 3 p. 300–306.

HOUSE M.A. 1989. A water quality index for river management. Water and Environment Journal. Vol. 3. Iss. 4 p. 336–344. DOI 10.1111/j.1747-6593.1989.tb01538.x.

Iraqi Drinking Water Quality Code number 14/2270. Drinking water standards. Iraqi Central Organization for Standardization and Quality Control. (2006).

KHAN F., HUSAIN T., LUMB A. 2003. Water quality evaluation and trend analysis in selected watersheds of the Atlantic Region of Canada. Journal Environmental Monitoring and Assessment. Vol. 88. Iss. 4 p. 221–242.

MANDALM P., UPADHYAY R., HASAN A. 2009. Seasonal and spatial variation of Yamuna River water quality in Delhi, India. Environmental Monitoring and Assessment. Vol. 10. Iss. 4 p. 661–665.

NAWAR O.A. 2008. Water quality index analysis for Al-Wihda water treatment plant in Baghdad city, Tigris River. Journal of Engineering. Vol. 14. Iss. 3 p. 2656–2668.

POONAM T. 2013. Estimation of tap water quality in Babylon Governorate/Iraq. International Journal of Advances in Chemistry (IJAC). Vol. 1. No. 1 p. 43–45.

REEN C.E. 1970. Investigating water problems: A water analysis manual. Chestertown, Maryland. LaMotte Chemical Products Comp. pp. 72.

SALIM B.J., BIDHENDI G.N., SALEMI A., TAHERYIOUN M., ARDESTANI M. 2009. Water quality assessment of Gheshlagh River using water quality indices. Environmental Science. Vol. 6. Iss. 4 p. 19–28.

STEINHART C.E., SCHIEROW L.J., SONZOGNI W.C. 1982. Environmental quality index for the Great Lakes. Water Resources Bulletin. Vol. 18. No. 6 p. 1025–1031. DOI 10.1111/j.1752-1688.1982.tb00110.x

YOGENDRA K., PUTTAIAH E.T. 2008. Determination of Water Quality Index and Suitability of an Urban Waterbody in Shimoga Town, Karnataka. Proceeding of the TAAL2007. The 12th World Lake Conference p. 342–346.

ZANDBERGEN P.A., HALL K.J. 1998. Analysis of the British Columbia water quality index for watershed managers: A case study of two small watersheds. Water and Environment Journal. Vol. 33. Iss. 4 p. 519–549. DOI 10.2166/wqrj.1998. 030.