GLOBAL JOURNAL OF ENVIRONMENTAL SCIENCES VOL. 8, NO. 1, 2009: 49 - 57
 1SSN 1596 - 6194

WATER QUALITY INDEX FOR ASSESSMENT OF WATER QUALITY OF RIVER RAVI AT MADHOPUR (INDIA)

ASHWANI KUMAR AND ANISH DUA

(Received 3 July, 2008; Revision Accepted 13 March, 2009)

ABSTRACT

Water quality of River Ravi, a tributary of Indus River System was evaluated by Water Quality Index (WQI) technique. A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. Eight most important parameters such as pH, total dissolved solids (TDS), total hardness, calcium(Ca), magnesium (Mg), total alkalinity, dissolved oxygen (DO) and electrical conductivity (EC) were taken for the calculation of WQI. The WQI values for the River Ravi ranged from 54.8 to 97.88. The values of WQI showed that the water was free of any impurities at the sampling site except for 2-3 months where its values were less than 70. Whenever there are human activities e.g., dam operations, water gets polluted to some extent, so the value of WQI decreases. It was found that the parameter which is required in least amount contributes a high statistical value to the index. It is concluded that WQI can be used as a tool in comparing the water quality of different sources. It gives the public a general idea of the possible problems with water in a particular region. The indices are among the most effective ways to communicate the information on water quality trends to the public or to the policy makers and water quality management.

KEYWORDS: WQI, River Ravi, Madhopur, India

INTRODUCTION

Rivers are large natural stream of water emptying into an ocean, lake, or other bodies of water and usually fed along its course by converging tributaries. Although they contain only about 0.0001% of the total amount of water in the world at any given time, rivers are vital carriers of water and nutrients to areas all around the earth (Wetzel, 2001). The water within a river is generally collected from precipitation through surface runoff, groundwater recharge and release of stored water in natural reservoirs, such as a glacier. Apart from being a rich source of fish, rivers indirectly aid cultivation by supplying water for irrigation. Anthropogenic influences as well as natural processes degrade surface waters and impair their use for drinking, industrial, agricultural, recreation or other purposes (Carpenter *et al.,* 1998 and Jervie *et al.,* 1998).

Rivers are central to many of the environmental issues that concern society, and they are studied by a wide range of specialists including hydrologists, engineers, ecologists, geologists and geomorphologists. Riverine water quality is an important issue for each stakeholder as it affects human uses as well as plant and animal life.

A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format. The WQI which was first developed by Horton in the early 1970s is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as lake, river or stream. After Horton a number of workers all over the world developed WQI based on rating of different water quality parameters. Basically a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Miller *et al.,* 1986). The different statistical approaches were followed for analyzing

Ashwani Kumar, Department of Zoology, Guru Nanak Dev University, Amritsar- 143005 (Pb) India
Anish Dua, Department of Zoology, Guru Nanak Dev University, Amritsar- 143005 (Pb) India

water quality data based on rank order of observations and factor analysis (Shoji *et al.,* 1966, Harkin, 1974). For the evaluation of water quality, WQI was applied to river water as well as coastal water (Dojlido *et al.,* 1994, Gupta *et al.,* 2003 and Avvannavar & Shrihari, 2007).

A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management and the public in a consistent manner. Similar to the ultra violet (UV) index or an air quality index, it can tell us whether the overall quality of water bodies poses a potential threat to various uses of water, such as habitat for aquatic life, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. WQI is a set of standards used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. A WQI also allows for comparisons to be made between different rivers. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life.

The CCME (Index incorporates three elements: *scope* - the number of variables not meeting water quality objectives; *frequency* - the number of times these objectives are not met; and *amplitude* - the amount by which the objectives are not met. The index produces a number between 0 (worst water quality) and 100 (best water quality). (Saffran *et al.,* 2001)

The objective of this study is to investigate the water quality of River Ravi at Madhopur, District Gurdaspur (India) which is a part of Indus River System, by using a Water Quality Index (WQI). Ravi (Figure 1) has its origin in India and finally falls into the Indus River System in Pakistan. It is a transboundary river and originates from Bangahal area of Dhauldhar (India). It flows through the valley of Chamba and leaves the Himalaya at Baseeli. With its tributaries, it drains the whole of Chamba valley. The thein Dam also called Ranjit Sagar Dam is constructed on River Ravi near Madhopur. Also two canals ABCL (Appar Bari Canal Link) and Rajasthan feeder originate from the river at Madhopur. The Oz River from Jammu & Kashmir joins River Ravi at Makora village (District Gurdaspur), Punjab, India. The river enters Pakistan near the village Tadyal/ Kot Nainan, Tehsil Shakargarh and flows for about 560 km to join river Chenab in Tehsil Kabirwala in Pakistan. There are wide flow variations during monsoon and winter season and peak flows are in the months of July and August, and low flow periods between November and February. The left bank of the river falls in the Punjab State and the right bank in Jammu & Kashmir State, about 24 km upstream of Madhopur head-works. The geographic coordinates of the sampling sites are 32^0 22.102 N and 75^0 35.935 E.

Figure 1: River Ravi showing sampling site

MATERIALS AND METHODS

Sample collection

Water samples were collected once every month from Madhopur (Figure 1) of the Punjab State of India. The analysis was done for three years i.e., January 2003 to December 2005.The samples were collected from the surface water of the River.

Analytical Methods

The parameters, water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS) and electrical conductivity (EC) were analyzed immediately at the sampling site using standard equipment (Century Water Analysis Kit). In the laboratory, the analysis of other parameters like acidity, alkalinity, total hardness, calcium and magnesium ions was done by volumetric analysis using standard methods given in Eaton *et al*. (1998), Trivedy and Goel (1986) and Tandon (1995). The air temperature was recorded using mercury thermometer.

Water quality index was calculated for each month for assessing the suitability of water for biotic communities and also drinking purposes. It was done by considering eight important physico-chemical properties using Central Public Health Environmental engineering Organisation (CPHEEO), 1991 & Indian Council of Medical Research (ICMR), 1975 standards.

In order to calculate WQI eight important parameters, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), total hardness, calcium (Ca) ions, magnesium (Mg) ions and total alkalinity have been selected. These parameters maximum contribute for the quality of river. The steps for WQI are:

Weightage

For water quality index calculation, we first have to know the weightage of each factor (Table 2) Factors which have higher permissible limits are less harmful because they can harm quality of river water when they are present in very high quantity. So weightage of factor has an inverse relationship with its permissible limits.

Therefore

$Wi \propto 1/Vi$

Or $Wi = k/Vi$

Where, k = constant of proportionality

Wi = unit weight of factor

Vi = maximum permissible limits as recommended by Indian Council of Medical Research/ Public Health Environmental engineering Organization

Value of k was calculated as:

$$k = \frac{1}{\sum_{i=1}^{8} \frac{1}{Vi}}$$

where

$$\sum_{i=1}^{8} \frac{1}{Vi} = \frac{1}{Vi(pH)} + \frac{1}{Vi(TDS)} + \frac{1}{Vi(Hardness)} + \frac{1}{Vi(Ca)} + \frac{1}{Vi(Mg)} + \frac{1}{Vi(TotalAlkalinity)} + \frac{1}{Vi(DO)} + \frac{1}{Vi(EC)}$$

The weightage of alll the chemical factors were calculated on the basis of this equation.

Rating Scale

Rating scale (Table 3) was prepared for range of values of each parameter. The rating varies from 0 to 100 and is divided into five intervals. The rating V_r = 0 implies that the parameter present in water exceeds the standard maximum permissible limits and water is severely polluted. On the other hand V_r = 100 implies that the parameter present in water has the most desirable value. The other ratings fall between these two extremes and are V_r = 40, V_r = 60 and V_r = 80 standing for excessively polluted, moderately polluted and slightly less polluted respectively. This scale is modified version of rating scale given by Tiwari and Mishra (1985).

Water Quality Index Calculation

Essentially, a WQI is a compilation of a number of parameters that can be used to determine the overall quality of a river. WQI is calculated for each month and is given in Table 4. The parameters involved in the WQI are dissolved oxygen, pH, total dissolved solids, hardness, calcium, magnesium, total alkalinity, electrical conductivity. The numerical value is then multiplied by a weighting factor that is relative to the significance of the test to water quality. The sum of the resulting values is added together to arrive at an overall water quality index.

WQI = Wi x Vr

i.e. Water Quality Index is equal to the product of rating (Vr) and unit weight (Wi) of all the factors.

$$Wi \times Vr = Wi_{(pH)} \times Vr_{(pH)} + Wi_{(TDS)} \times Vr_{(TDS)} + Wi_{(Hardness)} \times Vr_{(Hardness)} + Wi_{(Ca)} \times Vr_{(Ca)} + Wi_{(Mg)} \times Vr_{(Mg)} + Wi_{(Total\ Alkalinity)} \times Vr_{(Total\ Alkalinity)} + Wi_{(DO)} \times Vr_{(DO)} + Wi_{(EC)} + Vr_{(EC)}$$

The values of Vi, Wi and Vr are given in Tables 2 and 3. Hence by multiplying Wi and Vr we can get the value of WQI. It is basically a mathematical means of calculating a single value from multiple test results. The WQI result represent the level of water quality in a given water basin such as lake, river or stream. Similar WQI was given by Mariappan *et al.* (1998) by using nine important water quality parameters. Basic statistical analysis was done for each parameter.

RESULTS

Mean, variance and standard deviation are given in Table 1. The values of mean, standard deviation and variance indicate that there is large fluctuation in the values of EC, DO, Alkalinity and Total Hardness as compared to other parameters like temperature, pH, TDS, Ca and Mg.

Table 1: Summary of basic statistics for different water quality parameters (units are in mg/L except for EC which is in μS/cm; TDS in g/L; Temperature in ^{0}C; and pH has no units)

Water parameters	Minimum	Maximum	Mean	Std Deviation	Variance
Temperature	15.04	21.89	18.08	2.26	5.09
pH	7.07	9.1	8.07	0.49	0.24
DO	3.4	9.97	7.51	1.53	2.35
EC	120	372	173.69	46.12	2127.24
TDS	0.0768	0.208	0.11	0.03	0.0007
Alkalinity	18	172	58.29	41.39	1712.82
TH	80	730	242.97	118.82	14118.95
Ca	16.032	98.59	50.22	18.67	348.58
Mg	14.61	120.85	29.47	20.07	402.90

The physico–chemical parameters have shown temporal and spatial variations. The water was colourless and water temperature was almost low throughout the season. As shown in Table 1, total hardness (TH) ranged from 160 mg/l to 730 mg/l. In the present study, the calcium ion content of water ranged from 26.69 mg/l to 98.5 mg/l and magnesium ion at the sampling site ranged from 18.03 mg/l to 120.85 mg/l. The values of calcium and Magnesium ions at the sampling site were within the permissible limits except for one or two months during the survey. Water was slightly alkaline having pH ranging from 7.0 to 8.5. The electrical conductivity (EC) is a measure of the dissolved salt in a water sample. The changes in conductivity denote a changing composition and, on raw water, indicate that a change in treatment may be required. The values of EC ranged from 129 μS/cm to 222.3 μS/cm.

Total dissolved solids denote mainly the various kinds of minerals present in water. In the present investigation, the TDS value varied from 81.9 mg/l in the month of July 2003 to 142.2 mg/l. The value of the dissolved oxygen at the sampling site ranged from 3.4 mg/l to 9.97 mg/l. Total alkalinity is the measure of capacity of water to neutralize the strong acid. It is generally imparted by salts of carbonates, bicarbonates, phosphates, nitrates, borates, silicates etc. together with hydroxyl ions in free state (Trivedy and Goel, 1986). The total alkalinity at the sampling site varied from 18 mg/l to 172 mg/l. Nitrite, nitrate, ammonia and arsenic compounds were absent at the sampling site.

The ICMR/CPHEEO standards and unit weights for different water quality factors are shown in Table 2, and the rating scale for calculating WQI is given in Table 3. It is shown in Table 2 that the parameter which is required in the least amount has more unit weight. It is because the recommended water quality standard (Vi) is inversely proportional to the unit weight (Wi). The WQI rating (Table 3) shows excess and severe pollution when DO is low. Figure 1 represents the sampling site and Dam on river Ravi in Indian region and Figure 2 represents graph showing the comparison of WQI for three years 2003, 2004 and 2005.

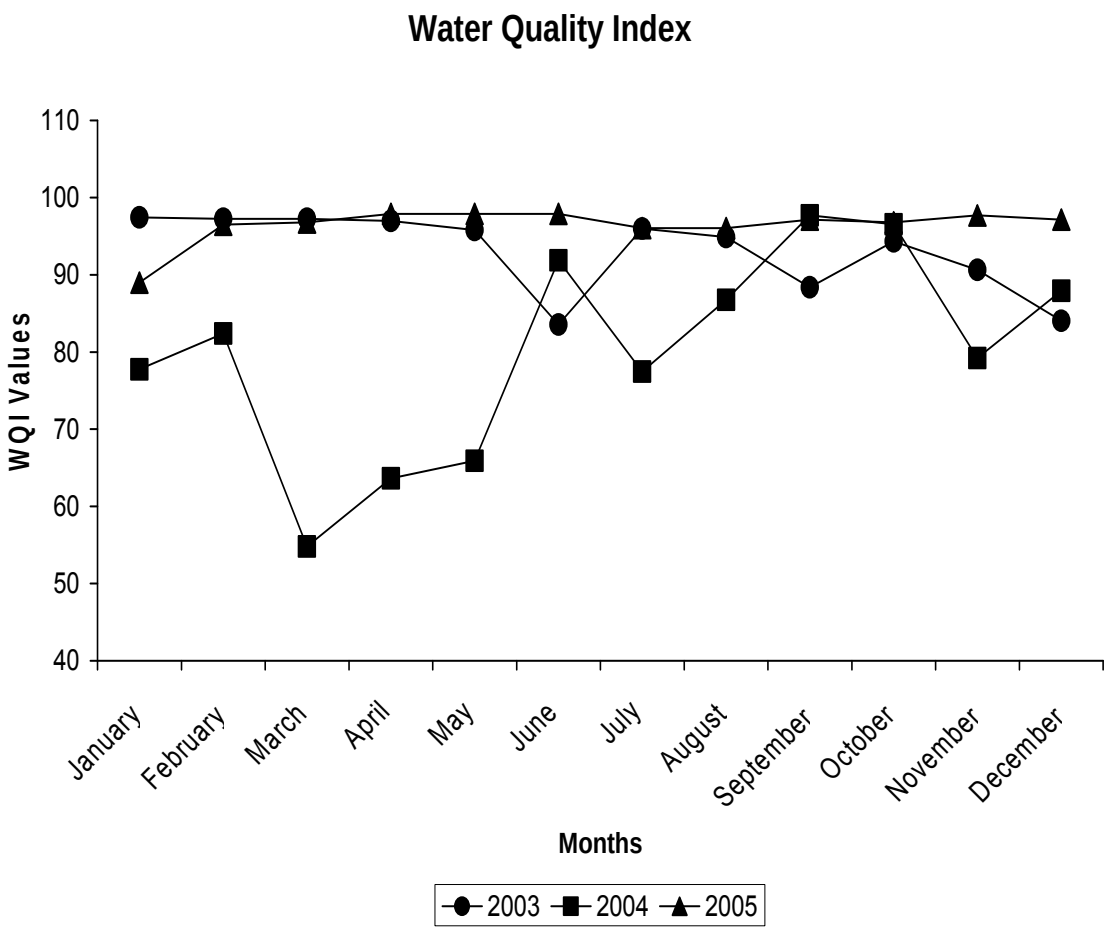

Figure 2: Graph showing the comparison of WQI for the years 2003, 2004 and 2005

Table 2: Water Quality Factors: Their ICMR/CPHEEO Standards and Assigned Unit Weights

Water Quality Factors	ICMR/ CPHEEO Standards (Vi)	Unit Weight (Wi)
pH	7.0-8.5**	0.322
TDS	<1500**	0.002
Hardness	<600**	0.005
Calcium	<75*	0.037
Magnesium	<50*	0.055
Total Alkalinity	<120*	0.023
Dissolved Oxygen	>5*	0.548
Electrical Conductivity	<300*	0.009

*ICMR Standards (1975) ** CPHEEO Standards (1991)

Table 3: Rating Scale for Calculating WQI

Physico- chemical Factors	Ranges				
pH	7.0-8.5	8.6-8.7	8.8-8.9	9.0-9.2	>9.2
		6.8-6.9	6.7-6.8	6.5-6.7	<6.5
TDS	0-375	375.1-750	750.1-1125	1125.1-1500	>1500
Hardness	0-150	150.1-300	300.1-450	450.1-600	>600
Ca	0-20	20.1-40.0	40.1-60.0	60.1-75.0	>75
Mg	0-12.5	12.6-25.0	25.1-37.5	37.6-50	>50
Total	21-50	50.1-70	70.1-90	90.1-120	>120
Alkalinity		15.1-20	10.1-15	6-10	<6
DO	>7.0	5.1-7.0	4.1-5.0	3.1-4.0	<3.0
EC	0-75	75.1-150	150.1-225	225.1-300	>300
Vr	100	80	60	40	0
Extent of Pollution	Clean	Slight Pollution	Moderate pollution	Excess Pollution	Severe Pollution

DISCUSSION

The values of WQI very much depend upon the value of dissolved oxygen in water. The higher the DO in water, the clearer the water. The value of DO at the sampling site is greater than 5 mg/l except for one or two months indicating that the water is clear at the sampling site. On the basis of the WQI, the quality of the water is categorized from very bad to excellent (Tiwari and Mishra, 1985). WQI ranges as follows:

Value of WQI	Quality of water
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

The water quality index for months of 2003, 2004 and 2005 is shown in Table 4. The higher values of WQI show that the water is very much clear i.e., it is free of any impurities at the sampling site except for 2-3 months when its values were less than 70. The values of WQI (Figure 2) for years 2003 and 2005 are almost identical but for the year 2004 there are fluctuations in the values, and it is found that water were comparatively polluted in the March, April and May. The fluctuation can be attributed to the changing of dam operations and hence the availability of water in river. As River Ravi in India is not explored for such studies the status earlier was not available. It is inferred from the results that overall quality of water is good at the sampling site. In this paper the application of water quality index approach to River Ravi in India had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the water quality. Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes (Bordalo *et al.,* 2001).

Table 4: Water Quality Index for the three years

Months/ WQI	2003	2004	2005
January	97.43	77.75	88.98
February	97.25	82.37	96.51
March	97.25	54.8	96.79
April	96.97	63.63	97.88
May	95.79	65.91	97.88
June	83.55	91.86	97.88
July	95.97	77.46	96.06
August	94.88	86.74	96.06
September	88.36	97.7	97.15
October	94.33	96.52	96.79
November	90.65	79.21	97.7
December	84.04	87.93	97.15

CONCLUSION

There are some limitations of WQI. For instance, WQI may not carry enough information about the real quality situation of the water. Also many uses of water quality data cannot be met with an index. But there are more advantages of WQI than disadvantages. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application" (McClelland, 1974). As WQI for three years were compared, it was found that the water was almost clear throughout the sampling time except for two or three months. High value of WQI supports aquatic fauna and flora. It is found from the calculation that parameter which shows the least favorable value gives a high statistical value to the index. Dissolved oxygen was found to be the most important parameter as it contributes the most for WQI calculation amongst eight parameters.

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