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Advances in Applied Science Research, 2013, 4(6):277-284

ISSN: 0976-8610
CODEN (USA): AASRFC

Determination of water quality index of river Asa, Ilorin, Nigeria

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ABSTRACT

Rivers are indispensible freshwater systems that are necessary for the continuation of life. The aim of the study was to assess some physicochemical parameters (pH, Dissolved oxygen, Temperature, Turbidity, Total dissolved solid, Nitrate, Ammonia, Iron, Lead and Chromium) of river Asa and present the complex water quality data of the river in a form that can easily be understood by the technical and non-technical personnel. To achieve the aim, the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was applied on the analytical results of the parameters to obtain a single value that was used to rank the river at each of the sampling station. The results (41.3, 42.3, and 43.6, 52.9) of the Water Quality Index showed that three of the four stations investigated can be ranked as poor and the remaining one as marginal. The implication is that the river failed Drinking Water Quality Index and thus not suited as a source of drinking water.

Keywords: CCME WQI, Drinking Water Quality Index, Ilorin, River Asa, Seasonal Variation, Water Quality Parameters.

INTRODUCTION

Rivers are indispensible freshwater systems that are necessary for the continuation of life. They are resources of great importance across the globe. The benefits of these systems to all living organism cannot be over emphasized as they remain one of the most essential human needs [1].

The quality of anybody of surface water is a function of either or both natural influences and human activities [2, 3]. Ajibade (2004) [4] enumerated a list of man's daily activities that require water application and that those roles played by river probably provide a basis for the adverse effect of its deficiency in either quality or quantity. Of all the human activities, industrial waste is the most common source of water pollution in recent times [5]. The quantum of these pollutants is such that rivers receiving these effluents cannot give dilution needed for their continued existence as good quality water sources.

The situation has aroused global concern over the public health impacts attributed to the deterioration of rivers as a result of pollution [6, 7].

Research has shown that eighty percent of all the diseases which claim lives in the third world countries are directly related to poor drinking water quality [8]. More than six million children die yearly (about 20,000 children per day) as a result of waterborne diseases linked to shortage of safe drinking water or sanitation [9].

The deterioration of water in physical and chemical properties is often slow and not readily noticeable as the water system adapt to the changes until an apparent alteration of the water occurs [10]. It becomes imperative to monitor the quality of the river in order to prevent it from further deterioration and ensure availability of quality water for domestic and agricultural purposes.

River Asa is of strategic importance to the people of Ilorin. The river is dammed just outside the city of Ilorin for water supply to the community and it is also used for irrigation along its course. The objective of the study was to assess seasonal variation of some physicochemical properties of River Asa and evaluate its water quality status using water quality Index.

MATERIALS AND METHODS

Study site

The study was conducted on River Asa, Ilorin, Kwara State, Nigeria. Ilorin has an area of about 100km^2 squares [11] and population of 847,582 as at the year 2007 [12]. Ilorin is on latitude 8 30`N and longitude 4 35`E and has an elevation of about 273 m to 333 m above sea level [13]. It is a humid tropical city characterised with both wet and dry seasons. The wet season starts in April and ends in October, while the dry season starts in November and ends in March [14].The mean annual rainfall is 1150 mm, while the mean annual temperature ranges from 25-28.9°C [15]. The city has a relative humidity which ranges from 65-80% [14].

River Asa is a major river of economic, agricultural, and environmental significance in the city as it supplies the bulk of water used by the people of Ilorin and its environs for different activities depending on its point of contact [16].

The river flows in south-north direction and occupies a fairly wide valley and goes a long way to divide Ilorin into two parts namely, the eastern and the western part [13, 17). It is an important tributary to the River Niger and is the longest river that flows across Ilorin city [4]. The course of the river enters the southern end of the Industrial Estate in Ilorin from Asa Dam located south of the estate and runs northwards through residential and commercial areas [6]. Apart from the industrial effluents that are being released into the river from manufacturing plants within the estate, it also serves as a recipient of domestic waste (sewage) and agricultural waste runoffs [2].

Sampling Procedure and Sample Analysis

Surface water samples were collected from four monitoring stations along River Asa during the wet and dry seasons of year 2012. The samples were all collected under high way bridges that cross the river (Asa, Unity, Emir and Amilegbe roads, respectively) within Ilorin city. The choice of the locations is to reflect virtually all the activities done on the river. Plastic bottles cleaned as recommended by Hanson (1973) [18] were used for the collection of the samples. The samples were then analyzed for some physical and chemical properties. The pH, dissolved oxygen, temperature and turbidity were measured with their respective meters. Total dissolved solid, Nitrate and Ammonia were determined using standard methods recommended by the American Public Health Association, APHA (1995), [19] and the heavy metals were determined using atomic absorption spectrophotometer (AAS).

Water Quality Index Calculation

Water Quality Indices make use of a 'single value' for the expression of overall water quality of a particular source at a certain time on the basis of some water quality variables [20]. The Indices aim at bridging the gap between technical personnel and general public by simplifying the complex way of presenting result so that it could be understood by all [21]. Selection of some significant water quality parameters is paramount to having good representation of all and to providing a simple indicator of water quality [22]. Though, a lot of water quality indices are being used for water assessment, some (if not all) seem to have a common similarity as they have their basis of comparing water quality parameters with their respective regulatory standards with interpretation of the results as good or bad [23].

The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was preferred a tool for the work due to its simplicity and ability to simplify Drinking Water Quality (DWQ) data without compromising the technical integrity of the data [24]. The Index compares the compliance of the observed data to a water quality standard or objective to give a score ranging from 0, indicating worst quality to 100 signifying the best quality [25, 26]. The Index is helpful in monitoring water quality change at a specific location over a stated period of time (often a year) and also in comparing directly among stations that employed the same variables and objectives. In doing so, the index quantifies for the station or among the stations the number of parameters that exceed or fall below the standards.

The index is flexible in terms of the standards (objectives) that are used for calculation, and the standard used is a function of the feed-back expected from the index [10]. This implies that when the interest is in determining drinking water quality Index, the established standards for its accomplishment is used and when the interest is in protecting the aquatic life, the standard for its achievement is also used. Basically, the index is calculated for three different uses [26]:

(a) Drinking Water Quality Index which includes drinking, recreation, irrigation, and livestock watering uses.
(b) Aquatic Water Quality Index which includes aquatic life and wildlife protection uses.
(c) Overall Water Quality Index, this is all uses including the protection of human health, aquatic ecosystems, wildlife etc.

In this study, Water Quality Index calculation was done by selecting ten parameters based on their importance. These ten parameters are pH, Total Dissolved Solids, Temperature, Dissolved Oxygen, Ammonia, Nitrate, Turbidity, Chromium, Iron, and Lead. CCME WQIs were computed for the four stations along the river using sets of established standards shown in Table 1 [26, 27]

The CCME WQI was based on the combination of three measures of variance from selected water quality standard (scope, frequency, amplitude). After determining CCME WQI, the water quality was ranked based on the categories shown in Table 2.

Table 1. Sets of established standard

Parameter	WHO	CCME
pH (mg/l)	6.5-8.5	8.5
DO (mg/l)	-	5
Temperature (^{o}C)	25	15
Turbidity (NTU)	5	5
TDS(mg/l)	500	500
Ammonia (mg/l)	0.2	1.37
Nitrate mg(mg/l)	50	48.2
Lead (mg/l)	0.01	0.01
Iron (mg/l)	0.3	0.3
Chromium	0.05	0.05

Sources: Ashok et al. (2006) [26] and WHO (2011) [27]

Table 2. Water Quality Index Scoring System

Rank	WQI
Excellent	95-100
Good	80-94.9
Fair	65-79.9
Marginal	45-64.9
Poor	0 – 44

Source : Tim (2012) [22]

Description of the Ranks
Excellent: Water quality meets all criteria for use as a source of drinking water.

Good: Water quality rarely or narrowly violates criteria for use as a source of drinking water.

Fair: Water quality sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water.

Marginal: Water quality often violates criteria for use as a source of drinking water by a considerable margin.

Poor: Water quality does not meet any criteria for use as a source of drinking water [22].

The detailed formulation of the WQI, as documented by CCME (2001) [21] and Amir *et al.* (2005) [28] comprises three factors as follows:

Factor 1: $F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ numbers\ of\ variables}\right) \times 100$ (1)

The measure for **scope** is F_1. This represents the degree of water quality guideline non conformity over the time period of interest in percentage.

Factor 2: $F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ numbers\ of\ tests}\right) \times 100$ (2)

The measure for **frequency** is F_2. This represents the percentage of individual tests which do not meet objectives (failed tests).

Factor 3(F_3) is the measure for **amplitude**. This represents the amount by which failed test values do not meet their objectives. This is calculated in three steps:

Step 1: Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

$$excursion = \left(\frac{Failed\ test\ valuei}{Objectivej}\right) - 1 \quad (3a)$$

When the test value must not fall below the objective:

$$excursion = \left(\frac{Objectivej}{Failed\ test\ valuei}\right) - 1 \quad (3b)$$

Step 2: Calculation of Normalized Sum of Excursions. The normalized sum of excursions, (*nse*) is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} excursion}{Number\ of\ Tests} \quad (4)$$

Step 3: Calculation of F_3. F_3 ($Amplitude$) is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \quad (5)$$

The CWQI is finally calculated as:

$$\mathrm{CWQ1} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (6)$$

Statistical analysis for the parameters studied was done for correlation with SPSS (16.0 software) package.

RESULTS AND DISCUSSION

Water Quality Index for each of the four stations along the river was determined for various seasons and for a year (which CCME WQI is often calculated) using the physicochemical parameters listed in Table 3. The values of the various scopes (F_1), frequencies (F_2), and amplitudes (F_3), with their respective water quality index are presented in

Table 4. During the dry season, the water quality index values of the river at the stations i.e Asa bridge, Unity bridge, Emir's road bridge and Amilegbe bridge were 52.8, 40, 42.6 and 40.3. The values showed that the water can be ranked as marginal at Asa bridge station, and poor at the other stations. During the wet season, the water quality index values were relatively higher, however, respective ranks remained the same for all the stations.

The average annual index values (Table 5) of the river (which range from 41.3 to 52.9) indicate that the water quality for drinking purposes can be ranked as marginal at Asa Bridge. This is because is because Asa bridge station is upstream of the river course in relation to other stations. The value decreased to below 45 making the water to be ranked as poor for the remaining stations.

The decrease in value to below 45 in three of the four stations is a reflection of different types of pollutants entering the river due to various anthropogenic activities at those stations. Pollutants such as discharge of untreated or partially treated effluent by various industries at the bank of river [6], domestic sewage, runoff water from agricultural lands near the banks of the river may be responsible for the poor water quality.

Table 3. Descriptive statistics of water quality parameters of River Asa

Station	Statistical tools	DO mg/l	pH	Temp. mg/l	Turb. NTU	TDS mg/l	NH_3 mgl	NO_3 mg/l	Pb mg/l	Fe mg/l	Cr mg/l
Asa	Mean	5.14	7.14	27.41	8.73	245.00	0.04	3.25	0.02	0.58	0.06
	Maximum	7.60	7.90	28.26	10.50	282.00	0.05	4.20	0.03	0.70	0.07
	Minimum	3.20	6.80	26.59	7.00	206.00	0.02	2.66	0.00	0.40	0.04
	SD	1.60	0.35	0.61	1.39	22.55	0.01	0.62	0.01	0.10	0.01
Unity	Mean	4.43	8.11	28.31	13.03	272.00	0.05	4.18	0.07	1.55	0.08
	Maximum	6.80	8.50	28.96	17.90	344.00	0.06	6.10	0.16	1.90	0.10
	Minimum	3.00	7.90	27.80	9.00	248.00	0.04	3.25	0.03	1.20	0.06
	SD	1.24	0.21	0.49	3.14	31.74	0.01	1.09	0.04	0.23	0.01
Emir	Mean	4.51	7.50	28.08	15.73	291.00	0.06	4.69	0.06	1.14	0.06
	Maximum	6.80	7.90	28.94	23.50	388.00	0.08	6.20	0.11	1.80	0.07
	Minimum	2.90	7.20	27.40	11.00	256.00	0.05	3.74	0.03	0.80	0.05
	SD	1.39	0.21	0.56	4.32	42.36	0.01	1.04	0.03	0.34	0.01
Amile-gbe	Mean	4.28	7.48	28.25	16.98	304.00	0.11	5.26	0.06	1.29	0.06
	Maximum	6.20	7.90	29.10	26.80	418.00	0.20	7.60	0.13	1.90	0.07
	Minimum	2.90	7.10	27.80	12.50	263.00	0.06	4.00	0.03	0.80	0.06
	SD	1.13	0.28	0.44	4.93	49.78	0.05	1.42	0.03	0.44	0.01

Table 4. Seasonal Variation of Water Quality Index at each Station

Station	**Dry Season**				**Wet Season**			
	F_1	**F_2**	**F_3**	**WQI**	**F_1**	**F_2**	**F_3**	**WQI**
Asa	60	48	28	52.8	60	48	26	53.2
Unity	60	60	60	40.0	60	55	55	43.3
Emir	60	58	54	42.6	60	55	50	44.8
Amilegbe	60	60	59	40.3	60	55	51	44.5

Table 5 . Average Annual Water Quality Index and the Ranking

Station	**Average Annual WQI**	**Ranking**
Asa	52.9	Marginal
Unity	41.3	Poor
Emir	43.6	Poor
Amilegbe	42.3	Poor

The low water quality rating observed is also supported by the analytical results of the physicochemical parameters (Table 3) chosen for WQI calculation. pH value is a very significant indicator which determine the suitability of water for various purposes [20, 29]. The pH value of the river at the stations fall within the threshold of 6.5-8.5, it however, has an average value which tend to be slightly alkaline except at Asa Bridge. This could be due to discharge of effluent in alkaline form as reported by Adebayo and Adeniran (2005) [30] and Adewoye (2013) [31]. The variations of pH between Asa Bridge and other sampling stations were statistically different at 5% (between upstream and downstream).

Turbidity is an important parameter when considering water for drinking purpose [10]. It was observed that the turbidity values at the four stations were higher than the allowable level recommended by the WHO and CCME for drinking water. The turbidity of the river increases downstream. The maximum and minimum average values (8.7 and 17.0 NTU) were observed at Amilegbe and Asa, respectively. The highest value was thus observed at Amilegbe. Turbidity rate of river is a product of suspended particles such as clay, silt, finely divided organic and inorganic matter, plankton and other microorganisms [10, 29]. It is however not surprising that the highest value of turbidity was recorded at Amilegbe station as studies by Salami (2003) [32] revealed that the station of all the four stations has the highest suspended solids and highest number of *Escherichia coli*. The variations of Turbidity between Asa and other sampling stations were statistically different at 5 %.

Dissolved Oxygen is considered the most important parameter for assessing water quality [33-35]. It regulates the distribution of flora and fauna [20]. Its deficiency has an adverse effect on river as the health of river largely depends on it [29]. During the wet season, high values (7.60, 6.80, 6.80, and 6.20 mg/l) were observed in each of the stations. However, the low values (3.20, 3.00, 2.91 and 2.90 mg/l) observed in dry season led to the average values being below CCME standard (5.0 mg/l) for all the stations except for Asa Bridge station. The least value was observed at Amilegbe. The low value of dissolved oxygen is probably due to discharge of industrial waste containing high concentration of organic matter and nutrient [36, 37]. The least value observed in Amilegbe is as a result of increase in plant and algal growth on the surface of water due to indiscriminate dumping of wastes around the bank of the river at the station leading to deoxygenating of the river as reported by Morrison *et al*. (2001) [38]. The variations of dissolved oxygen between Asa Bridge and other sampling stations were statistically insignificant at 5% level.

Total Dissolved Solid is a vital parameter which imparts an unusual taste to water and lessen its usage as potable water [39]. In natural water, it is composed of the sulfate, bicarbonate and chloride of calcium, magnesium and sodium [10]. The highest value (418mg/l) was observed in dry season at Amilegbe. However, all the observed values were within the permissible level recommended by WHO and CCME for drinking water. The variations of total dissolved solids between Asa and other sampling stations were statistically significant at 5% level.

The observed values for Ammonia in all the stations were within the permissible level recommended by WHO and CCME. The maximum and minimum average values (0.11 and 0.04 mg/l) were observed at Amilegbe and Asa Bridge, respectively. The statistical analysis showed a significant difference between Amilegbe and the remaining sampling stations at 5% level.

Nitrate is an undesirable ion in water. The maximum and minimum average values (5.26 mg/l and 3.25 mg/l) were observed at Amilegbe and Asa Bridge, respectively. All the observed values however fell within the threshold values.

According to Morrison *et al*. (2001) [38] dumping of industrial and agricultural wastes into water increases the level of nitrates. Our findings are in agreement with the submissions of earlier works [31, 40]. There was a difference between Asa Bridge and other sampling stations at 5% level of significance.

The concentration of the heavy metals (Lead, Iron and Chromium) exceeded the permissible level recommended by WHO and CCME for drinking water at the two seasons. The highest average concentration of the metals (0.07 mg/l for Pb, 1.55 mg/l for Fe and 0.08 mg/l for Cr) were recorded at Unity in dry season. The high values recorded for the heavy metals in all the stations of the river were due to industrial discharge of effluent , indiscriminate disposal of domestic waste, runoffs, and atmospheric deposition [10,41-43). This observation is supported by the findings of Adekola and Eletta (2007) [6] and Okeola *et al.* (2010) [40]. The statistical analysis of Heavy metal showed a significant difference between Asa Bridge and the remaining sampling stations at 5%.

Temperature is not an issue in pure water, but is of great concern in polluted water. The observed temperature values of the river at all the stations under consideration were above the permissible level recommended by WHO and CCME. The maximum and minimum values (28.3^{o}C and 27.4 ^{o}C) were recorded at Amilegbe and Asa Bridge, respectively. This was expected because of the relationship between dissolved oxygen and temperature [29]. A river with low amount of dissolved oxygen is usually high in temperature. The probable causes of high temperature in the river include water withdrawals during dry season for irrigation and other purposes, and erosion and sedimentation during the wet season [44]. The fluctuation in the temperature of river depends on the season, station location, sampling time and temperature of the effluent entering the river [45]. The values obtained agree with the findings of other researchers [32, 40, 31] .The variations in temperature between Asa Bridge and other sampling stations were statistically significant at 5% level.

CONCLUSION

Seasonal variation of some physicochemical properties of River Asa was assessed and the river water quality status was evaluated using CCME water quality Index. The result of study revealed that the river is not suitable for usage as drinking water, even at Asa Bridge that has been considered as less polluted site because it is upstream of the Industrial Estate from where a lot of the pollutants are being released into the river. The presence of industries such as Soap and Detergent Industries Limited, Uniform Nigeria Limited, 7up Bottling Company, TUYIL Pharmaceuticals Nigeria Limited, Dangote Flour Mill, Butterfield Bakery, Nigeria Bottling Company (Coca-Cola) Ilorin Plant, KAM Industries Nigeria Limited, Glister Company and agricultural activities around the bank of the river impacted negatively on the river. There should be caution in using the river for irrigation also, as drinking water quality Index includes irrigation. More so, the study showed that application of Water Quality Index is a useful tool in assessing the overall quality of river.

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