PRELIMINARY ASSESSMENT OF THE CURRENT POLLUTION STATUS OF THE RIVER ATUWARA, NIGERIA, WITHIN AN INDUSTRIAL SITE: A BIVARIATE APPROACH

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ABSTRACT

With the increase of industrial growth within developing countries, there is a large tendency for increased pollution within the area. The surrounding rivers may be one of the culprits serving as a waste stream; however, as these rivers are used for agricultural, domestic and recreational purposes, as a cautionary measure, a preliminary assessment of the River Atuwara was carried out to know its status using water quality parameters such as dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), total dissolved solids (TDS), electrical conductivity (EC), coliform count and temperature were examined within certain portions of the River Atuwara, situated in South-West Nigeria. From the study, the descriptive statistics showed that BOD, pH, DO, TDS, EC, coliform count and temperature had mean values of: 3.719±3.34; 6.715±0.48; 4.51±0.49; 113.8±36.67; 174.11±54.62 1036±202 and 25.17±0.313, respectively. The values of pH, DO and coliform count obtained were above the World Health Organization (WHO) and FEPA standards for drinking water. In addition, a principal component analysis (PCA) was conducted on the parameters, which showed that BOD, DO, pH, coliform count and temperature are important parameters to be considered in assessing river water quality. We recommend that adequate treatment of the effluent from the source be carried out as well as using waste treatment plants with natural aerators, to improve the degradation of pollutants. Also, there should be strict follow-up of existing river and watershed management policies, to reduce deliberate and accidental spills.

Keywords: dissolved oxygen, pollution, degradation, river management, dispersion coefficient.

1 INTRODUCTION

Industrialization gained momentum in the 1960s in Africa, as the majority of African countries gained independence: it was a means of self-reliance for many of such brand-new countries, with citizens having the belief that industrialization would pave the way for economic growth and help the continent reach its macroeconomic objectives. This was later achieved to some extent, so much so that human progress these days is expressed in terms of industrial potential and prosperity. Other advantages of industrialization include improvements in the standard of living of the people, availability of goods at cheap prices, availability of options for goods and services, etc.; however, industrialization can bring about unplanned growth, inflation, and displacement of manpower in industries; thereby leading to unemployment, and increased pollution of land, air and water [1], [2].

In recent times, many rivers have fallen victims of pollution that comes from industrial and municipal activities, which causes various imbalances in the river environment and as such, becomes detrimental to the health of the aquatic organisms and humans [3]–[5] who consume the water, unaware of the hazard it constitutes [6]. Conversely, consumers of

WIT Transactions on Ecology and the Environment, Vol 234, © 2019 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/RBM190211

polluted surface water have the potential to suffer from gastrointestinal, respiratory, dermatological and other forms of disease, which is usually dependent on the concentration of pathogens in the stream, as well as the duration of exposure time [7].

In addition, in a recent study carried out by Emenike et al. [8], it was revealed that most people residing within this river find it less stressful and cost effective to source water from the river. This holds, as there are a lot of problems associated with public boreholes meeting the demands of the public in most rural communities in Nigeria. These problems include an unreliable power supply, which is needed to pump water from the Water Cooperation in that area to other nearby sources were the citizens can access it; a poor distribution network system; and the proximity of the people to these sources, among others. In addition, according to Ezilo and Dune [9] and Adedokun and Agunwamba [10], it is rather unfortunate that most rivers flowing around industrial layouts in Nigeria are usually heavily polluted, due to indiscriminate dumping of wastes by these industries, and the effluents contain pollutants such as heavy metals, organic toxins, solids, and more; however, the pollution of surface water bodies is not limited to industrial effluents. According to several studies [11]–[13], there is a possibility for surface water bodies to become polluted if the environment around them is polluted. Also, the quality and sufficiency of water at the disposal of the people is the measure of their quality of life [14]; therefore, for good water quality, the environment where the river is situated has a role to play. In Ado-Odo/Ota, the local government area where the river is situated and where a study was carried out, there are over 100 large- and small-scale industries, out of which 35 industries discharge untreated or partially treated effluent into the river [14]. Therefore, for a non-toxic and sustainable environment, there is a need for thorough and continuous assessment of the rivers in Nigeria, to ensure the control of waste lies within the assimilative capacity of such rivers [10]. The aim of this study is to conduct a preliminary assessment of the status of the River Atuwara in South-West Nigeria, as it is under threat from industrial pollution and the significance of the pollution must be determined.

2 METHODS AND MATERIALS

2.1 Study area

The River Atuwara, popularly known as the river Iju, passes through the Iju community in Ota, which is an urban industrial center. The Ado-Odo/Ota Local Government Area (LGA) is the most populous LGA in Ogun state. With a population of 526 565 700 330 people, it lies between latitude 60 30’N-60 50’N and longitude 30 02’E-30 25’E [15]. The drainage area of the Atuwara watershed is 147 333 km^2; 50% of which is forested, 10% which is for agriculture, 25% is water, 7% is for residential purposes and 8% for commercial purposes. The River Atuwara has many confluences where other rivers merge with it, as well as tributaries where it feeds into other smaller streams and rivers. The segment of the river under study covers about 1 km, within which various waste discharge points were identified including an industrial effluent discharge point that discharges waste water into the river continuously, all day long.

It was observed that numerous activities are being carried out within the river, such as: the dredging of sand, bathing, laundry; and also there is a water intake structure belonging to the Ogun State water works, which was identified within the watercourse. This intake structure pumps water, which is then treated and distributed to the public taps within the area.

2.2 Field method

This comprises a reconnaissance survey, as well as getting familiar with the river and the environment at large; the determination of the sources of pollution; and the identification of the various uses the river is being put to.

2.3 Sampling visit

Ten sampling stations were marked out for data collection with wooden pegs. The trajectory was marked at intervals of 100 m in a sampling length of 1km. River water samples were collected at those points. Samples were collected before the major effluent inlet point, to determine the effect of the effluent discharge from a popular alcoholic beverage company on the river's water quality. Parameters were determined in-situ; meanwhile, others were determined in the laboratory. Parameters determined in-situ include: pH, temperature, stream velocity, depth, width, dissolved oxygen (DO) and conductivity; while the biochemical oxygen demand (BOD), total dissolved solids (TDS) and coliform count test were carried out in the laboratory, situated in the department of Civil Engineering and the department of biological sciences at Covenant University, respectively. The stream velocity was measured using the global water flow probe, depth was taken along the river at cross-sections using a Speedtech Portable depth sounder, and the water temperature, pH, DO, electrical conductivity (EC) and TDS were measured using the portable Hanna multi-parameter tester (H1 2020 series).

2.4 Laboratory analysis

All laboratory analyses was carried out at Covenant University in Ota Ogun state, Nigeria. The water samples meant for BOD were taken in clean 75 ml plastic bottles and transported immediately to the laboratory where it was incubated at 4°C until the BOD test was carried out. BOD was carried out [16]. Water samples for bacteriological analysis were collected in sterilized containers and kept at a temperature of 4°C; then transported to the biological science laboratory unit in Covenant University for analysis.

2.5 Data analysis

Descriptive statistics and a principal component analysis (PCA) were carried out on all obtained parameters. The PCA used a new set of variables, which it generates as smaller than the original set of variables, but retains the samples' original information [17]. To identify the relationships between various waste water parameters that were present in the river water samples, the data was analyzed using SPSS and a Pearson correlation matrix. Furthermore, Pearson correlation was also used to determine the effect of industrial effluents on the general water quality of the river.

3 RESULTS AND DISCUSSION

The descriptive statistics showed that BOD, pH, DO, TDS, EC, coliform count, temperature and TSS had mean values of: 3.719±3.34 mg/l; 6.715±0.48 mg/l; 4.624±0.49 mg/l; 113.8±36.67 mg/l; 174.11±54.62 µs/lcm, 1036±202 MPN/100 ml and 25.17±0.313°C, respectively; and when compared with the WHO standard for drinking water, it was observed that the mean values of pH, DO and coliform count were above the drinking water standard; hence, the general health of communities along the river is at risk, as it was discovered that the communities around the river drink the water, as well as use it for other domestic purposes without any form of treatment. The sampling points with their corresponding physiochemical properties; as well as some waste water characteristics, are presented in Figs 1–6.

From Fig. 1 below, it is seen that there is a considerable drop in the pH of the water, from 6.69 to 5.53 at point B, suggesting that the studied effluent is acidic, thereby making it unsuitable for both recreation and domestic purposes; furthermore, the acidic nature of the river will affect the conduits' usage for the water supply within the area. The water supply networks would be prone to corrosion of both concrete and metal pipe networks, which would further impair the quality of water supplied within the area. In addition, the increase in pH of the river is responsible for the corresponding high values of EC and TDS that were recorded at point B.

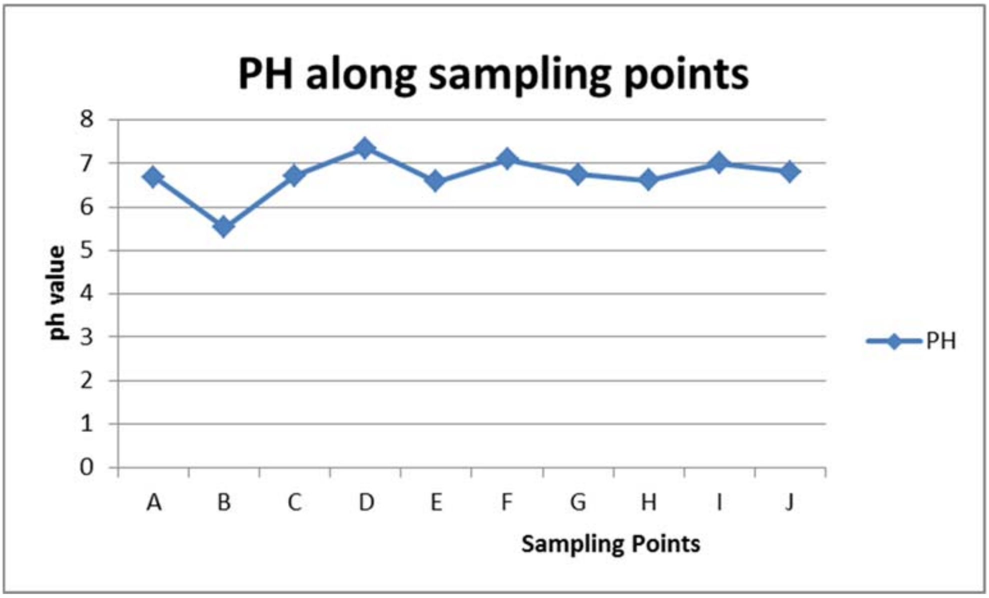

Figure 1: Plot of pH against sampling points.

Figs 2 and 3 show the variability of EC and BOD along the river. They also reveal that EC and BOD were high at point B, as the numbers varied from 159 µs/cm–329 µs/cm and 1.14 mg/l–8.71 mg/l, respectively. The reason for this variation is because the effluent from the alcoholic beverage company situated around the river is discharged at point B, and as the direction of flow is from point A to point B, this shows point A is free from the addition of pollutants by the company; furthermore, this adds up to the reason for the decrease of both parameters, as the flow moves downstream. Fig. 3 also reveals that the river has a strong self-cleaning capacity, as the values of the BOD were reduced greatly along the river, except for point H. The reason could be the presence of other non-point sources of pollution being discharged into the river. In addition, Fig. 4 shows the plot of TDS along the river, and is seen to have a similar relationship with the EC. Conversely, it reveals that the effluent entering the river contains high levels of dissolved solids. Also, the high values of EC and TDS, having values of 329 µs/cm and 218 mg/L, respectively, indicates that the effluent contains a lot of dissolved solids as well as metals [18], [19].

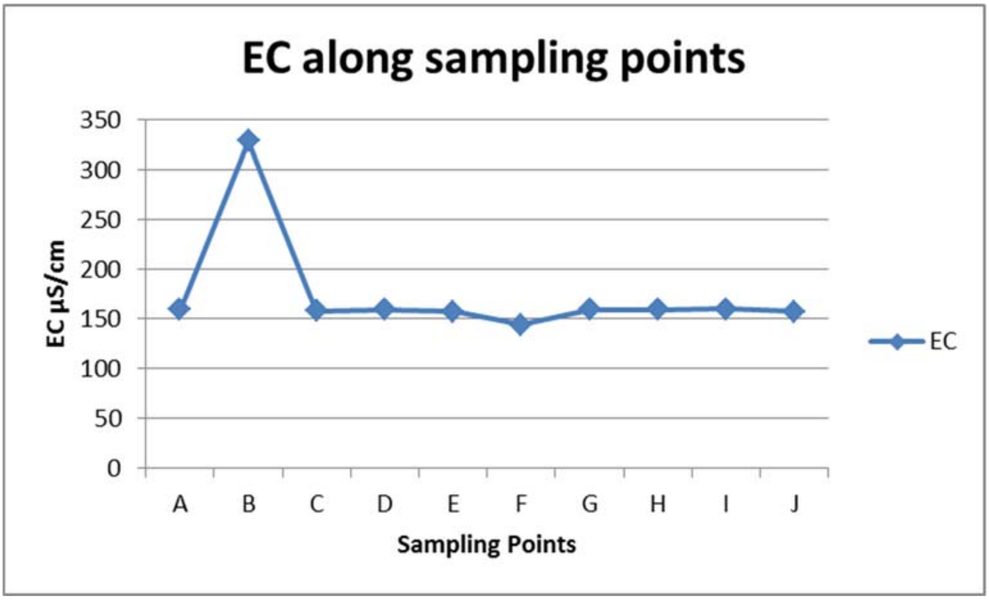

Figure 2: Plot of EC against sample points.

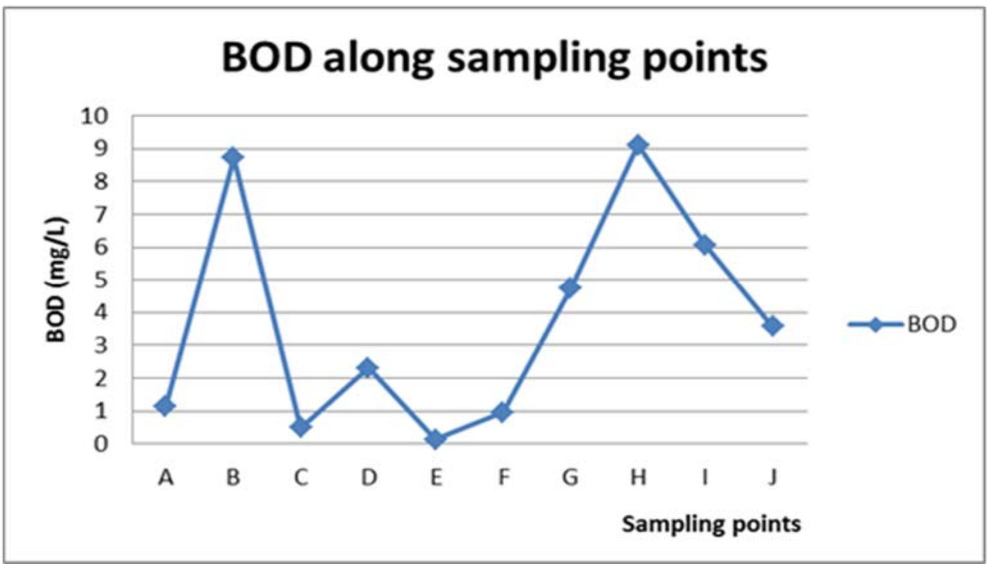

Figure 3: Plot of BOD against sample points.

Fig. 5 presents the plot of DO along the river: it could be observed from this figure that point A and J had the highest and the same DO values of 5.13 mg/L; this shows that all points in the river have DO levels below the expected 7 mg/L. This suggests the level of pollution is on-going in the River Atuwara, with point B having the lowest DO value, 3.97 mg/L. The

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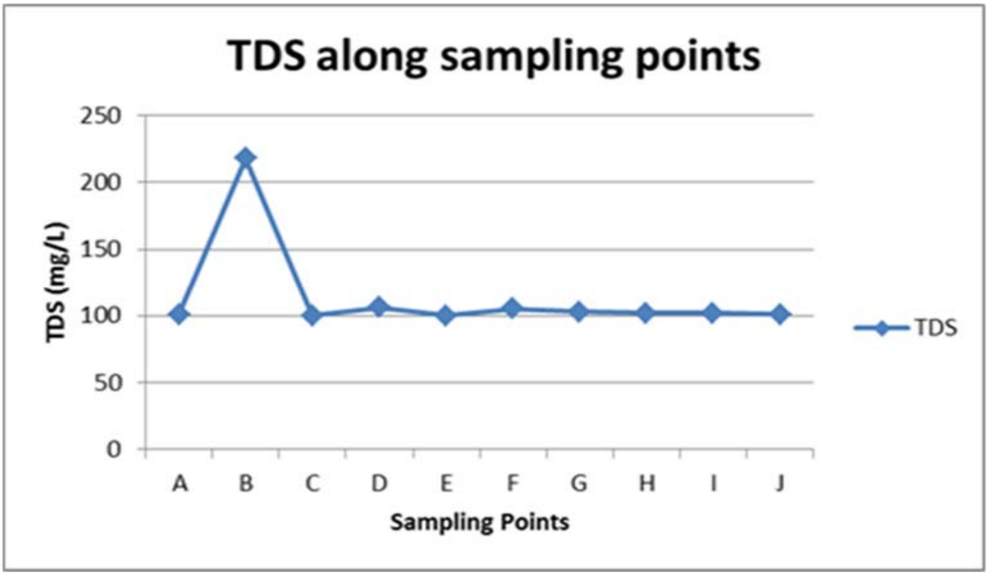

Figure 4: Plot of TDS against sample points.

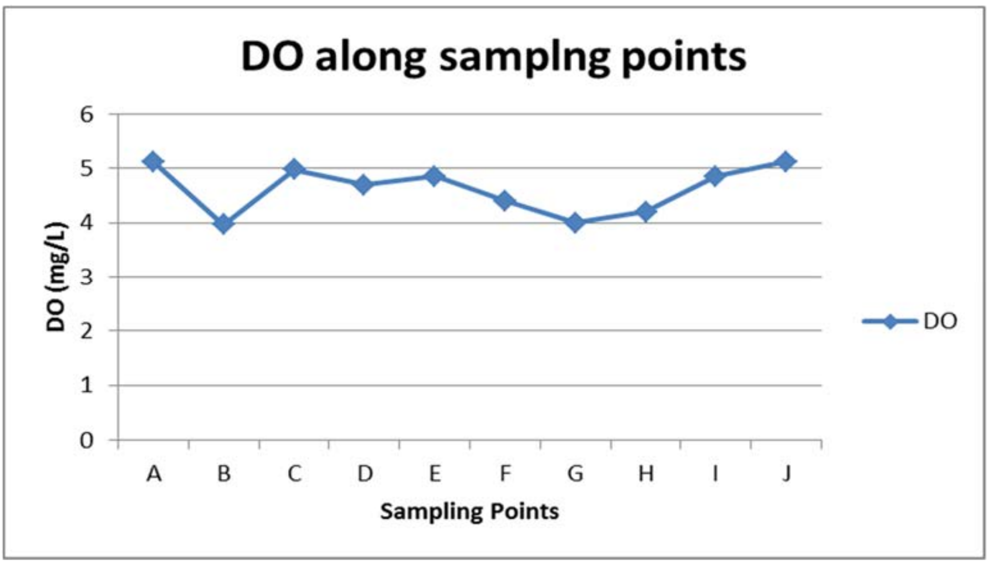

Figure 5: Plot of DO against sample points.

low DO value at point B is recorded because at that point, the alcohol beverage industry within the river vicinity discharges its effluent directly. This change increases the presence of microorganisms; therefore, reducing the available oxygen, as it is utilized for degradation of the effluent. In addition, since the point before the effluent discharged around the study has low DO values, it simply shows that a great portion of the river is under industrial pollution threat. This is because there are several industries on the upstream side of the river that also discharge an uncontrolled volume of waste into the river. That is the reason why even the point before our own study area, Point B, has low DO. Fig. 6 presents the plot of total coliform count along the river; it is observed that just point C has a value of 460 MPN/100 mL, as against the unanimous value of 1100 MPN/100 mL, indicating there is a very high bacteriological waste load in the river. The high amount of microbes present could be attributed to industrial activities; but also human activities such as farming, fishing, bathing, as well as disposal of human and animal wastes into the river.

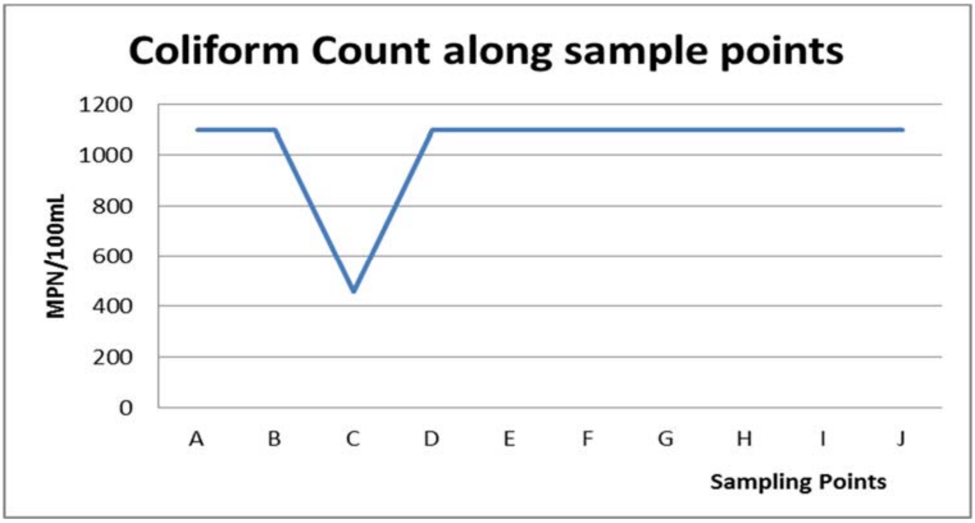

Figure 6: Plot of coliform count against sample points.

PCA was conducted with the set of variables analyzed during the experimental process. This was carried out to identify the contribution of the parameters to the general water quality of the River Atuwara. In Table 1, the variables are grouped into five different groups; however, it is theorized that all of the variables are contributors in the water quality analysis, except temperature. The main function of a PCA is to reduce dimensionality through finding a new set of variables, meanwhile regaining the initial information; hence, in considering

Table 1: Component score coefficient matrix.

	Component				
	1	2	3	4	5
VELOCITY	0.000	-0.003	0.013	1.033	0.660
pH	0.000	-0.004	-0.002	0.013	1.265
TEMP	0.000	0.003	0.010	0.141	-0.276
BOD	0.001	0.326	-1.165	0.275	0.625
TDS	0.309	-7.699	-4.180	-0.754	-0.694
EC	0.692	7.503	4.798	-0.105	1.486
DO	0.000	0.002	0.014	-0.396	0.920

Note: Extraction method: Principal component analysis.

component 5 from Table 1, it was revealed that velocity, pH, BOD, EC, and DO are active contributors in analyzing the water quality of the river with coefficient matrix values: 0.660, 1.265, 0.625, 1.486 and 0.92, respectively. This is because at component 5, all the variables have significant values greater than 0.05.

The Pearson correlation matrix was used to investigate (statistically) the effects of industrial effluents as well as other pollutants on the physicochemical and bacteriological quality of the River Atuwara, by determining the individual contribution and relationships of the variables with each other.

Table 2 below shows the correlation matrix, as well as the relationship between the parameters. From Table 2, it was observed that there is a negative relationship between EC and pH, with a correlation value of -0.877, which implies that an increase in EC would result in a decrease in pH. This relationship is evident from the results obtained in this research. As effluents are discharged into the river, there is a corresponding reduction in the pH, as it becomes more acidic. This pH reduction will threaten aquatic life and reduce water quality. Similarly, pH also has a negative relationship with TDS and from Fig. 4, it is seen that at point B, where the industrial effluent enters the river, the TDS is very high (218 mg/L) and with a corresponding low pH; hence, further justifying the acidity of the effluent. Considering TDS and EC, it is seen that there is a positive correlation of 0.993 between them, this further concludes that the EC value obtained during the water quality check is a function of the dissolved solids found in the water samples.

Table 2: Inter-variable correlation matrix.

	Velocity	pH	Temp	BOD	TDS	EC	DO	Coliform count
Velocity	**1.000**	-0.388	0.174	0.062	0.557	0.547	0.192	-0.417
pH	-0.388	**1.000**	0.053	-0.497	-0.843	-0.877	-0.315	-0.004
Temperature	0.174	0.053	**1.000**	-0.396	-0.335	-0.278	0.206	-0.820
BOD	0.062	-0.497	-0.396	**1.000**	0.529	0.549	-0.184	0.341
TDS	0.557	-0.843	-0.335	0.529	**1.000**	0.993	0.356	0.132
EC	0.547	-0.877	-0.278	0.549	0.993	**1.000**	0.356	0.104
DO	0.192	-0.315	0.206	-0.184	0.356	0.356	**1.000**	-0.338
Coliform count	-0.417	-0.004	-0.820	0.341	0.132	0.104	-0.338	**1.000**

In the same vein, EC and velocity also have a positive correlation between themselves, with a correlation value of 0.547. This implies that high stream velocities would cause the pollutants to travel faster, which is also seen in the relationship between TDS and velocity, with a correlation value of 0.557. Since TDS accounts for the dissolved solids, the correlation simply means that the higher the velocity, the faster these dissolved solids are dispersed in the river. Temperature has a negative correlation of -0.820 with coliform count; hence, an increase of temperature could cause a decrease in the number of coliform bacteria present in the river. In addition, BOD and EC have a positive correlation of 0.549, that means the more pollutants enter the river, the higher the BOD, as well as the conductivity of the river. Similarly, TDS and BOD were seen to have a correlation of 0.529, which implied that an increase in TDS would also cause an increase in BOD.

In order to determine if the observed correlations between the water quality parameters were significant, the data was subjected to paired sample t-tests. The results of a statistical analysis are presented in Table 3. From the test, only correlations present are those having a significant value < 0.05.

Table 3 shows the inter-parameter correlations and their corresponding significance. With the null hypothesis rejected when p > 0.05; it is observed that between EC and pH; pH and TDS; and TDS and EC, the relationships between them are significant. Contrarily, the correlation between EC and velocity; EC and BOD; TDS and velocity and TDS and BOD were all found not to be significant.

Table 3: Paired samples correlations of water quality parameters.

		N	Correlation	Sig.
Pair 1	EC and pH	9	-0.883	0.002
Pair 2	pH and TDS	9	-0.852	0.004
Pair 4	TDS and EC	9	0.993	0.000
Pair 5	EC and Velocity	9	0.541	0.133
Pair 6	EC and BOD	9	0.545	0.129
Pair 7	TDS and Velocity	9	0.548	0.127
Pair 8	TDS and BOD	9	0.519	0.153

4 CONCLUSIONS

We investigated the contribution of industrial effluent on the water quality of the River Atuwara. This was done mainly because for a non-toxic and sustainable environment to exist, there is a need for thorough and continuous assessment of the rivers in Nigeria, to safeguard the control of waste going into the river bodies, within their assimilative capacities. Our results show that the average values of BOD, pH, DO, TDS, EC, coliform count, and temperature were 3.719±3.34 mg/l; 6.715±0.48 mg/l; 4.51±0.49 mg/l; 113.8±36.67 mg/l; 174.11±54.62 µs/cm; 1036±202 MPN/100 ml and 25.17±0.313°C, respectively.

By comparing our values obtained for the Atuwara with the WHO drinking water standard pH, DO and coliform count, they were found to exceed the drinking water standard by 6.5–8.5; 7 mg/L and 10 [20], hence the water was rendered unfit for drinking.

In conclusion a strict, as well as total adherence to the policies already in place is required to improve the water quality status of Nigerian River Atuwara; which is widely used for bathing, drinking, as well as for irrigation purposes. Furthermore, adequate treatment to reduce the organic waste load of the effluent being discharged into the river is recommended. Natural aerators, such as a roughened side, wall and bed enough to cause variation in depth and hydraulic jumps should be integrated into the wastewater treatment plants, to increase the DO content required for the degradation of organisms.

Based on the water quality of the river, stringent laws and enforcement of those laws against indiscriminate disposal of effluent are needed as soon as possible, around the country. This is because the general misconception that the rivers will just take care of the wastes discharged into them does not consider the assimilative capacity of the river, which is a function of the river dynamics, such as velocity, depth, topography, etc. Also, adequate enlightenment should be given to the inhabitants of communities around the river, as to how to use the river water for domestic use. Direct drinking of the water before treatment should be discouraged, as well as indiscriminate dumping of waste by the community inhabitants.

ACKNOWLEDGEMENT

The authors graciously thank the management of Covenant University (in Ota, Ogun State) for continued support of this research.

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