International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **9(4),** 45-54, October **(2020)** *Int. Res. J. Environmental Sci.*

Evaluation of specific organic and inorganic pollution indicators in a homeland river

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Available online at: www.isca.in, www.isca.me
Received 11th April 2020, revised 21st September 2020, accepted 12th October 2020

Abstract

The objective of this study was to develop a biannual database for selected organic and inorganic river pollution indicators. The DO, BOD and COD levels alongside TSS and TDS concentrations were determined using standard protocols. The compiled database consisted of 5 aforementioned parameters, 12 monthly variables and 5 sampling points for each month during the biannual study generating over 60 data per specific parameter with 60 data per variable, per season per annum. April/May recorded highest values of TSS at "UT" sampling point, which was the peak of rainy season and had maximum values of TSS at 60.38 mg/L exceeding the APHA, EU, EPA and FME discharge limits, except WHO standards. Highest TDS (68.20 mg/L) was in 2014 (Oct/NOV) at "DS" sampling point which exceeded FME and EPA permissible limits but well below WHO, EU and APHA standards. Observation shows that 2015 was an active DO year much more than 2014 and DO decreased significantly as water flows downstream. Moreover, the highest COD concentration was 290 mg/L at "NB" sampling point during Oct/Nov that was high but below APHA standard. However, the BOD levels between the seasons showed no seasonal variation within each year, which might be due to active and regular discharge of organic pollutants from abattoir source throughout the biannual study. ANOVA analyses showed that BOD and TSS data were statistically more accurate than other parameters. In conclusion, the river is unsafe, unclean and unacceptable for public consumption, recreation, sensitive fish habitation, requires pollution preventive, and control measures.

Keywords: Discharge, downstream, effluents, pollutants, river, upstream.

Introduction

Good River water quality often times are persevered because of controlled local and industrial effluent discharge activities[1]. Sometimes however, locals perform unregulated activities at odd hours while inevitable industrial effluent discharges are recorded during effluent treatment failures, transportation leakages, production accidents, manufacturing explosion or even earthquakes. These are foreseeable pollutants driving low water quality due to anthropogenic activities[2]. Notorious among anthropogenic activities are excessive fertilizers leaching from farmland, poultry/animal house waste discharges, combustion of fossil fuels and dye effluents that adversely affect the aquatic ecosystem with man at the apex of this chain. Charkabi and Sakizadeh [3] studied spatial variations of water quality parameters in a polluted wetland in Iran. Their findings showed that agriculture and urban activities were the major pollutant sources suggesting localized sources. In addition, localized river pollution can occasionally emanate from nearby infrastructural development, sprawling of farmland and urban land making the water slightly polluted[4,5].

Another study conducted by Magadum, Patel, and Gavali[6] identified that their studied river became polluted after receiving discharged effluents heading towards downstream. Similarly, the leading causes of river contamination and pollution have also been attributed to food and beverage effluent discharge, municipal sewage, and agricultural runoff. These defectively affect river water quality as studies showed that parameters such as total suspended solids (TSS), Total dissolved solids (TDS), biochemical oxygen demand (BOD), dissolved oxygen (DO), and chemical oxygen demand (COD) are major indicators of river pollution levels and river water quality[7,8].

This fact is true because inorganic pollutants and largely organic pollutants posses' threats to urbanization and global climate. A research work calculated for the first time historical and future in-stream BOD concentrations in global river networks[9], identified that despite self-purifying ability of Rivers with low level of BOD levels; a growing number of human populace will be continuously affected by organic pollution. This biochemical oxygen demand (BOD) refers to the decomposition of organic substances by bacteria under aerobic conditions and the amount of oxygen they consume during mineralization, which is usually higher in wastewaters. BOD therefore measures the oxygen absorbing capacity of an effluent. On the other hand, Dissolved oxygen (DO) is the main indicator of the ecological health of aquatic ecosystems. The DO defines the capacity of the body of water to assimilate the imposed load by itself or with the help of re-aeration through oxygen absorbed mainly from the atmosphere and through photosynthesis. Then again, Chemical Oxygen Demand (COD) is a measure of the quantity of oxygen required to oxidize the organic matter (biologically available, inert organic matter) in a waste sample, under specific conditions of oxidizing agent, temperature, and time into carbon dioxide and water, and oxidizable inorganic matter[10-12].

A study conducted by Islam et al.[13], and another independent research by Dewata and Adri[14] showed that there exists a very strong positive correlation between biochemical oxygen demand (BOD) and chemical oxygen demand (COD). This also extends to a correlation relationship with dissolved oxygen (DO). Hence, several authors have studied the correlation and significance of BOD, COD and DO in water pollution assessment to understand their significance. For example, the impact of cement effluent on downstream water quality was indicated by reduced dissolved oxygen (DO) alongside high values of BOD[7]. In addition, in another study conducted in Sungi Benus, Malaysia using water quality index, confirmed that both COD and BOD indicated the levels of organic domestic waste[15]. Similarly, using stream water quality model, Al-Dulaimi[16] observed that high levels of BOD in the river may due to discharges of untreated wastewater from different point sources and suggested that water quality modeling provides better understanding of the on-going physical and chemical processes in a river. In addition, another research used BOD/COD Ratio as an Indicator for River Pollution[17,] while Susilowati et al.[18] worked on dynamic factors that affect DO/BOD concentration. They found that BOD/COD ratio is a good indicator for pollution measurement in river as well as predicting the relationship of BOD and COD with organic matter content in the river water. Accordingly Akagha et al.[19, 20] and co-researchers studied quality of Aba River in Abia state, Nigeria. Their findings confirmed unacceptable water quality levels due to heavy metal contaminated and large presence of anions. Hence, there is the need for routine evaluation and assessment. Therefore, the present study was carried out in Aba River during Rainy and Harmattan seasons of 2014 and 2015 to determine the biannual levels of TSS and TDS, together with DO, BOD and COD. Secondly, to establish the effect and pollution types caused by pollutant levels over the river body, thirdly to assess the impact of received pollutants to a certain tolerable limit for beneficial purposes via water quality index. Finally, establish ANOVA interpretation of collected data.

Materials and methods

Description of the study area: A vivid description of the study river with adequate map was previously discussed in our paper[19,20]. However, a brief explanation is provided herein. The Aba River in Southeastern Nigeria is a tributary of Imo River that empties into the Atlantic Ocean. Having considered some factors like effluent discharge points, nearness of sampling points to communities and accessibility to research crewmembers, the river was mapped into five sampling points of 100 m river stretch. The Upstream zone "**UT**" at 05°076' 93"N. The "**NB**" at 05°16'551"N, 007°22'430"E and midstream zone having the longest distance were "**PZ**" at 05°16'472"N, 007°22'749"N. The Abattoir "**AB**" 05°72'62"N, 007°22' 434"E., 007^{o}22'668"E. while the downstream zone "**DS**" at 05°72'75"N, 007°22'448"E. Local canoe men ferried research crew across the river for sample collection. Each station was separated from the other by a distance of about 20 meters. The PZ or P sampling area hosts the PZ Cussons Plc, NB or N sampling area hosts the Nigerian breweries Plc, while the AB or A sampling area hosts the abattoir. Also for simplicity of representation, the upstream and downstream are also referred as 'U' and 'D' sampling stations respectively.

Sample Collection and analyses: In order to account for seasonal variation of Rainy and Harmattan seasons in Nigeria, bimonthly sample collection was adopted as follows: June/July, August/September, October/ November, December/January, February/March and April/May for the period of 2014 and 2015. Polyethylene Sample bottles were washed with non-ionic detergent and rinsed with water passed through deionizer and twice through water distiller herein called (DDW.) Afterwards the washed sample bottles were labeled with respect to location/collection points. Three water samples were collected after rinsing severally from each sampling point using the bottles for DO, BOD, COD, TSS and TDS analyses. Afterwards they were kept in a flask stacked with ice to maintain a temperature of below 4^{o}C before transport to FUTO chemistry Laboratory for analyses[11,21]. The DO, BOD and COD physico-chemical analyses of the selected water quality parameters were conducted following standard analytical protocols[22]. Total Dissolved Solids, (TDS) and Total suspended Solids (TSS) were analyzed according to standard APHA protocol. This methodology was fully described by a recent article by Aniyikaiye et al. 2019[23].

Results and discussion

Statistical analysis of variables: The analytical data obtained from selected physicochemical parameters of Aba River in the year 2014 and 2015 are presented in Table-1 below. All results were average of triplicates from each sampling point and reported in four significant figures of milligram per litre concentration (mg/L).

Total Solids, suspended solids and dissolved solids: TSS: The determined values of TSS is presented in Table-1 while the graphical representation is shown in Figure-1. The minimum value determined was 27.52mg/L in Harmattan at PZ location while the maximum value measured was 60.37mg/L during rains at UT sampling point. The average values of Harmattan as seen in Figure-1 was higher than the rains, while from February to March, the TSS concentration of rains exceeded that of Harmattan season. Unfortunately, the maximum values of TSS at 60.38mg/L exceeded the APHA, EU, EPA and FME discharge limits, except WHO standards[22,24-28].

The effluents discharged into the river are therefore major contributors to high TSS as can be confirmed in Table-2. Accordingly,[23] the high concentrations of TSS might be suggested to be the presence of inorganic particulate matters such as binders, pigments and additives present in paint. Similarly Ipeaiyeda and Onianwa[29], reported effluents from food and beverages industries and other suspended materials such as coagulated milk, particles of cheese curd and concentrate are contributors of high TSS. This will increase the cloudiness or non-transparency of the river as well as impair photosynthetic process of aquatic plants. Thus, it interferes with purification of the river due to formation of sludge beds. A closer look at the Figure-1 shows that during 2015 Harmattan higher volume of TSS is found due to accumulated waste sucked in as surface run-off. Oct/Nov of both years had lowest flow, which is beginning of Harmattan. While, April/May gave highest values, which is the peak of rainy season. Moreover, it depicts that higher volume of waste flows downstream especially in Harmattan season. This findings corresponds with conclusion of previous work[20] that highest phyto-chemical activity occurs in Harmattan while rainfall dilutes TSS activity[1]. Thus based on water quality index table, the river water belongs to class II and Class III. Hence, minor purification and treatment is required but doubtful for survival of sensitive fish species[4].

TDS: The TDS values for different sampling sites are shown in Table-1 and Figure-2 for both rains and Harmattan seasons of 2014 and 2015. As expected the average TDS values were higher than TSS. The TDS recorded lowest concentration to be 40.48mg/L at NB sampling point during June/July (rains) of 2015 while the highest (68.20mg/L) was in 2014 (Oct/NOV) at DS sampling point. Although, the values were high, however, the only exceeded FMC and EPA permissible limits but well below WHO, EU and APHA standards. Accordingly, the findings correlated with Aniyikaiye et al.[23], that the TDS is a measure of organic matter, inorganic salts and other dissolved materials inside the water. As noted earlier, this value confirms the presence of dissolved organic and inorganic solvents, surfactants and chemical reagents.

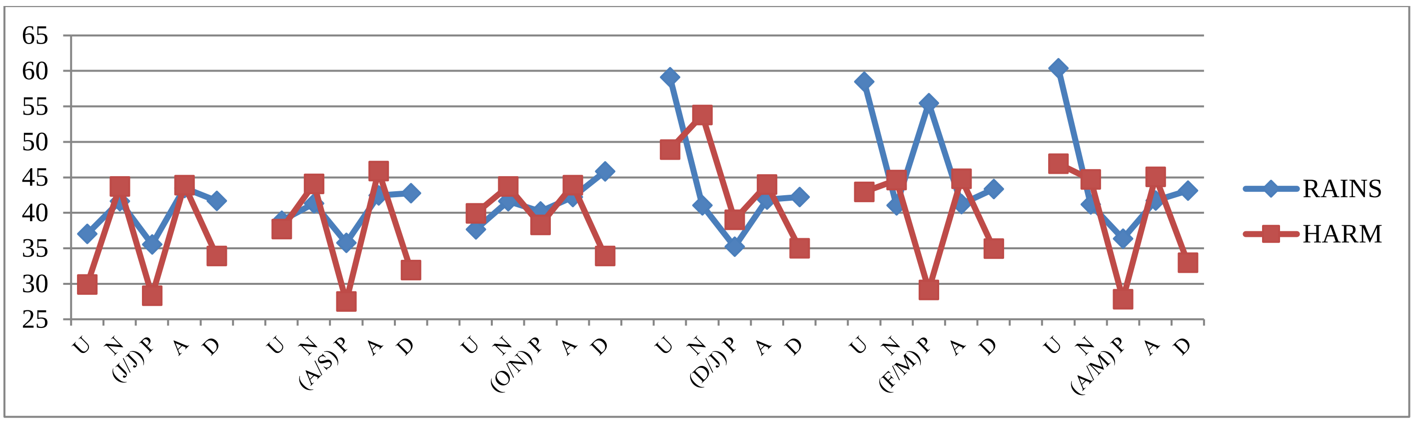

Figure-1: Bi-monthly variation graph of TSS on biannual basis (Source: from this research work).

Table-1: Data obtained from Aba River analyses.

		Rains/Harmattan (2014)					Rains/Harmattan (2015)				
June/July 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	6.016	50.17	200.5	37.03	63.95	7.038	59.40	209.3	29.92	48.88
	NB	6.321	51.54	227.4	41.64	55.42	6.296	62.33	271.5	43.71	40.48
	PZ	5.481	57.46	184.9	35.53	63.92	6.328	74.76	202.6	28.32	45.89
	AB	6.643	49.13	179.1	43.51	68.91	3.818	50.71	183.8	43.88	46.06
	DS	5.496	58.26	155.0	41.69	67.64	4.846	59.27	174.4	33.92	46.08
Aug/Sept 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	5.391	50.20	169.2	38.88	63.08	7.407	59.00	168.4	37.70	49.01

	NB	5.483	51.35	220.4	41.33	56.09	6.230	62.07	271.8	44.06	41.11
	PZ	5.050	63.89	173.9	35.76	63.78	6.306	73.67	203.7	27.52	44.97
	AB	5.427	52.89	180.1	42.44	64.09	3.884	45.91	182.1	45.88	46.96
	DS	5.455	57.77	144.2	42.77	67.23	4.881	58.99	143.8	31.92	45.80
Oct/Nov 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	5.691	62.63.	170.4	37.65	62.90	7.307	79.40	173.0	39.92	48.88
	NB	5.581	60.21	223.6	41.62	60.66	6.313	62.33	290.2	43.71	43.48
	PZ	5.520	61.23	172.1	40.21	63.90	6.264	74.76	220.8	38.32	45.89
	AB	5.402	63.22	181.2	42.23	67.90	3.886	66.71	207.1	43.88	46.06
	DS	5.836	68.01	164.7	45.85	68.20	4.709	59.27	165.8	33.92	46.08
Dec/Jan 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	5.293	55.11	171.6	59.11	62.12	6.875	58.80	167.1	48.91	46.89
	NB	5.170	56.21	226.2	41.04	66.09	6.324	61.38	273.6	53.78	46.58
	PZ	4.786	61.90	175.6	35.21	64.97	6.298	75.01	201.5	39.01	45.99
	AB	5.041	53.19	178.9	41.87	64.77	4.112	45.91	182.9	44.01	47.02
	DS	5.144	59.01	146.1	42.22	67.55	4.631	58.37	155.1	34.99	42.08
Feb/Mar 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	5.778	60.17	190.5	58.50	52.01	7.142	58.90	168.8	42.95	42.81
	NB	6.179	60.84	227.1	41.05	56.23	6.231	61.93	272.4	44.61	42.08
	PZ	6.413	59.88	174.5	55.44	64.21	6.221	73.72	201.9	29.12	44.91
	AB	6.358	55.19	178.4	41.23	63.76	5.313	49.42	195.0	44.78	45.76
	DS	6.124	57.30	182.3	43.34	66.12	5.113	55.22	162.5	34.98	46.12
April/May 2014/2015	SITE	DO	BOD	COD	TSS	TDS	DO	BOD	COD	TSS	TDS
	UT	5.402	54.43	170.7	60.37	62.91	8.315	62.41	200.8	46.91	49.26
	NB	5.400	53.23	227.1	41.19	57.89	6.337	61.54	273.4	44.70	44.88
	PZ	5.419	55.77	175.5	36.36	64.88	6.248	75.60	201.8	27.82	44.91
	AB	5.649	58.21	179.1	41.73	63.70	3.885	47.70	182.7	45.08	45.76
	DS	5.592	56.90	144.1	43.11	66.88	4.840	60.21	145.1	32.99	47.01

Table-2: River/effluent water standards from global, international and national standards[22-27].

	TSS (mg/L)	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)
WHO	500	500	6	250	50
EU	35-60	118	5.0-9.5	125	25
EPA	30	30	5-6	160	30
APHA	30	500	5.95-8.56	400	60
FME	0.75	0.75	4	30	6

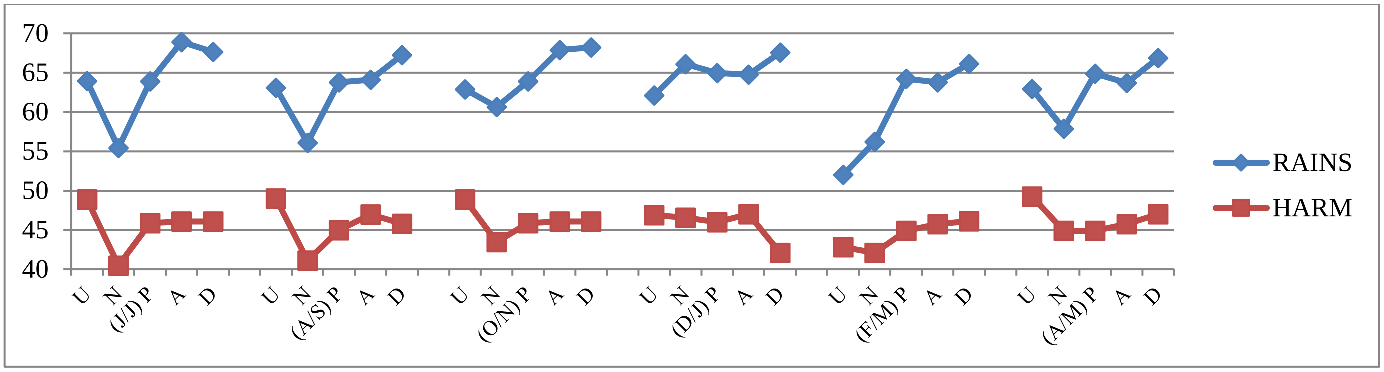

Figure-2: Bi-monthly variation graph of TDS on biannual basis.

In addition, the inflow of these pollutants such as fertilizer and other treatment chemicals[3] via leaching and poor land use activity may result to sludge bed development. While dissolved solids containing bicarbonates, carbonates, sulfates, and chlorides and calcium would contribute to increased alkalinity level of the water downstream as the effluent disperses in the river. Moreover, from Figure-2. It appears that 2015 was an active year for TDS in correlation to TSS activity in same year. In addition, the diagram similarly indicates that larger volume of TDS was moved downstream in 2015 as against 2014 with lesser volume of dissolved solids and matters. Accordingly, this may be due to sedimentation in 2014 because of reduced current velocity and water levels and consequent reduced floodwaters. Finally, it could have also resulted from higher rainfalls in 2014 or evapo-crystallization process as well as low rainfall in 2015 that led to low dilution of the river[30]. Thus based on water quality index[7], the river is classified under water quality index class 2 and 3, and said to be of poor quality.

Measurement of organic pollution (DO, BOD and COD): DO: Dissolved oxygen data are presented in Table-1 together with graphical expression in Figure-3. The minimum determined value was 3.886mg/L at AB during Aug/Sept of 2015 while the highest value was 8.315mg/L at UT during same April/May of 2015 despite the influx of effluent that could have diluted DO as the river flowed downstream. A closer observation shows that average DO values ranged between 5-6 mg/L. Apparently, no sampling point exceeded the APHA and EU standards. Also most sampling points exceeded FME limit but were within EU, EPA and APHA standards. At “AB” sampling sites, values ranged from of 3-4mg/L such as "AB" in June/July, Aug/Sept, Oct/Nov as well as Dec/Jan of 2015. This is anticipated to be good for aquatic growth life and fishes. Then again, no sampling site value was below 3mg/L mandatory values in any month or year. Furthermore, all the sampling sites during rains and Harmattan seasons of 2014 were below 6mg/L except in Feb/March and June/July. This shows that the river likewise has a healthy ecosystem and steady flowing water as similarly reported by Ibrahim and Kutty[15].

Accordingly, research by Ipeaiyeda and Obaje on cement effluents[7] discussed equally that the discharged organic effluents (food and beverage, livestock waste, domestic household waste and agricultural waste) at upstream and midstream sites is decomposed by micro-organisms in the river. However, during the breaking down process of the organic pollutant, the micro-organism consumes the available oxygen in the river. Then aquatic life becomes susceptible to toxic substance found in the effluent. As this increases, the level of dissolved oxygen becomes used up. Furthermore, a study by Susilowati et al.[18] similarly indicated that during rainy season (April-September) that values of DO increased due to rains that will eventually increase river aeration. Also from Figure-3. it was clearly seen that 2015 was an active DO year much more than 2014 and DO decreased significantly as water flows downstream, albeit partly because of decrease in water velocity downstream[30]. Hence, based on water quality index, the evaluated river status is class II and class III pollution index. Thus, it is polluted but still acceptable; nevertheless, minor purification is required[4].

COD: The two lowest COD permissible limit standards were 30mg/L from FME and 125mg/L EU standards. Based on our findings the lowest COD value was 143mg/L determined at "DS" sampling point in Aug/Sept of 2015 as seen in Figure-4. This means that all COD results exceeded the FME Nigerian standard and EU standard, thus requiring pressing attention. On the hand, EPA permissible limit is 160mg/L and was not exceeded by "DS" sampling points in 2014 of June/July, Aug/Sept, Dec/Jan and April/May an indication of high COD activity during Rainy season that runs from April to September. Also during 2015 of April/May, Dec/Jan and Aug/Sept of 2015 the COD values were below EPA permissible limit. Fortunately the highest COD concentration was 290mg/L at "NB" sampling point during Oct/Nov which was high but a little above APHA standard of 250mg/L. Also strikingly during 2014 season no COD value exceeded APHA standard of 250mg/L while 2015 season had several sampling sites exceeding APHA limits. Thus based on our definition, these indicated that more oxygen was available at favorable conditions with resultant higher concentration of COD.

The presence of this high COD might be due to influx of effluent with high decomposable organic matter present in wastewaters near "NB" sampling point[7]. Moreover, the presence of highly oxidizable inorganic compounds were contributory to the high concentration of chemical oxygen demand in the samples, together with the inability of the localized industries to reduce the concentration of COD levels before discharge limits [23,31]. Observation of the COD mechanism from Figure-4 shows that the pattern of discharge and rainfall appear to be in same trend over the two-year period/season. Secondly, all sampling points peaked at "NB" sampling point another indication of high COD activity at "NB" sampling point. In addition, observation shows that as the river flows from point "UT" to "DS", it picks up organic debris that peaks at "NB" and starts decomposing rapidly as it flows downstream towards "DS". This principal agrees with other works that looked at BOD/COD ratio as pollution indicators[17] and factors that affect DO/BOD[18]. And verified that quantity of available oxygen is a good indicator of pollution measurement/index. Thus based on water quality index, the river is graded into Class V of water quality index and therefore described as not acceptable for public water consumption, recreation and sensitive fish species[4].

BOD: Like COD findings, the 2015 BOD activity was higher than 2014 BOD activity as show in Figure-5. The Biological oxygen demand recorded the lowest value as 49.13mg/L at "AB" sampling point in June/July during 2014. The value was also lowest at 45.91mg/L in 2015 at Dec/Jan. These values where well above FME standard, EU permissible limit and EPA standard. Hence, the river requires monitoring and discharge guidelines based on their limits. Also all sampling stations exceeded 50mg/L WHO standard except sampling points at "AB" in June/July, Aug/Sept Dec/Jan, Feb/Mar, April/May in 2015, while June/July of 2014 recorded lowest BOD.

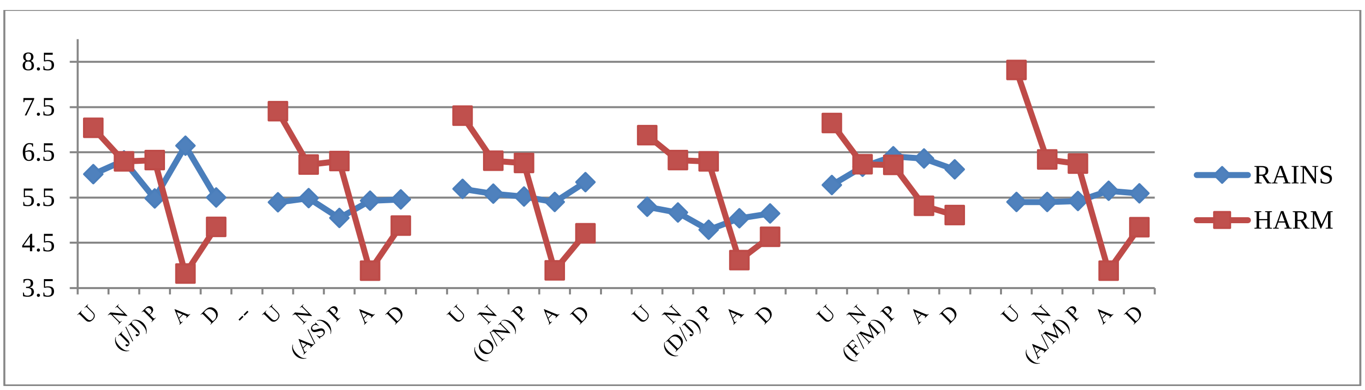

Figure-3: Bi-monthly variation graph of DO on biannual basis.

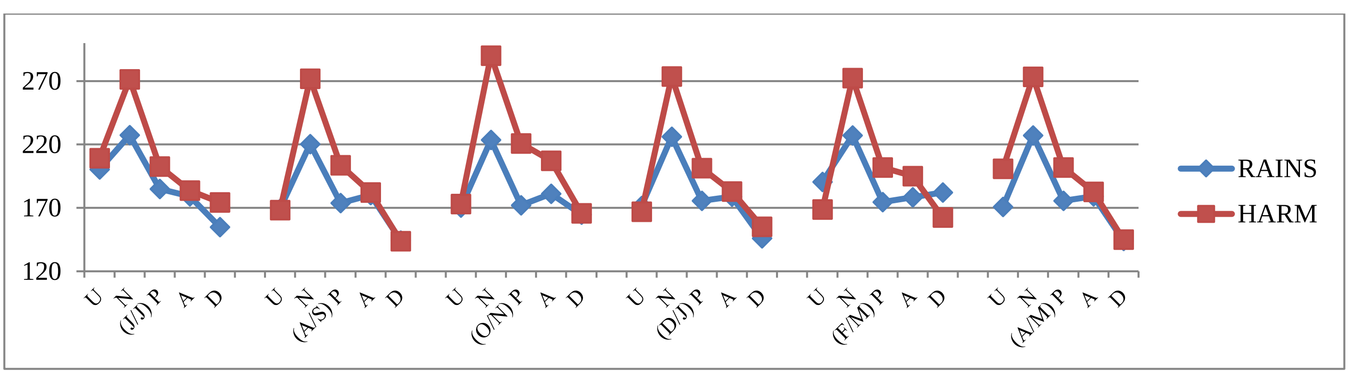

Figure-4: Bi-monthly variation graph of COD on biannual basis.

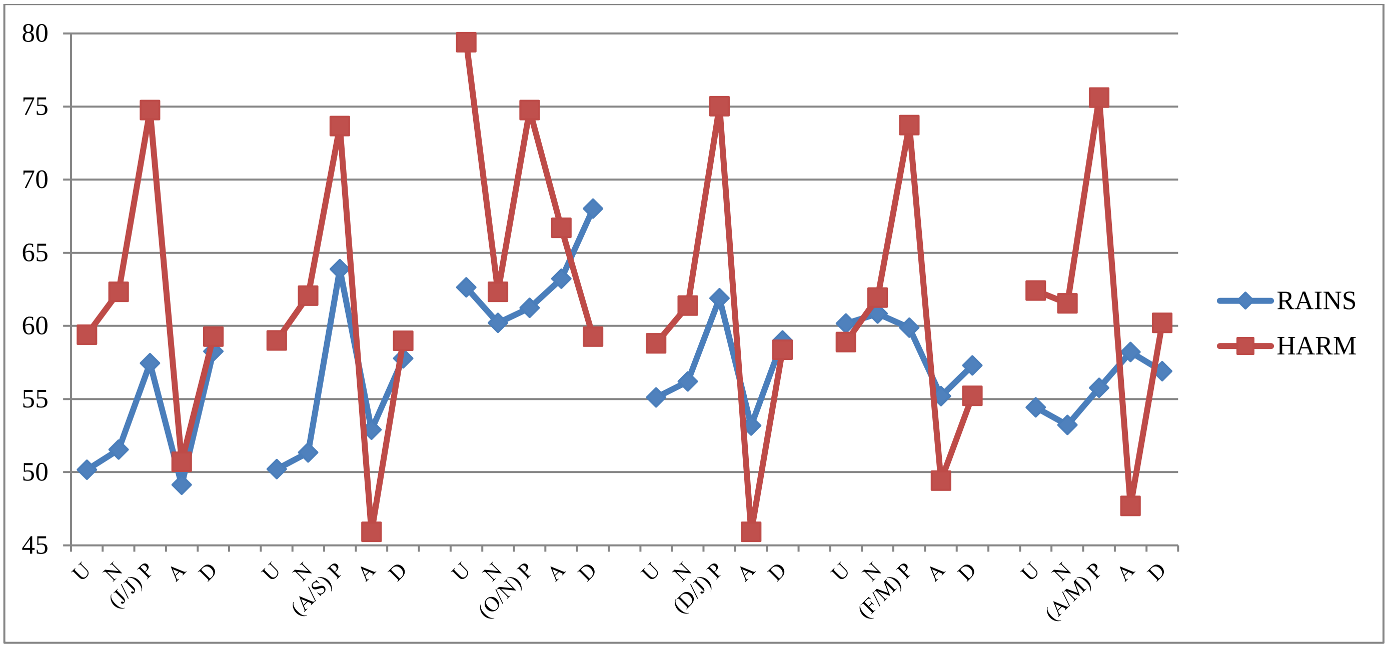

Figure-5: Bi-monthly variation graph of BOD on biannual basis.

The highest BOD concentration (79.40mg/L) level was determined at "UT" sampling stations during Oct/Nov of 2015 while 2014 season was 61.90mg/L at "PZ" sampling station. Both values exceeded the BOD concentration standard for APHA and WHO standard. This shows that higher BOD activity is on-going at those sampling sites and the river is polluted largely having exceeded 6.00mg/L for aquatic freshwater. This problem might be associated with bacterial population, food manufacturing waste and low levels of oxygen[7]. Subsequently "PZ" area hosts PZ manufacturing firm a leading manufacturer of soaps, household chemicals, personal care products and natural oils. In addition, another reason might be due to the active decomposition process of organic matter by microbes consuming oxygen[1].

Also, this may have been due to a sudden input of organic waste from neighboring industries and municipal domestic waste. This equivalently might be caused when the river flowed at very low velocity, hence a small addition amount of waste would result to increase in the BOD value[13]. Similarly[6], it has been observed a negative co-relationship with DO from their findings. Alternatively, untreated sewage disposal and municipal waste run-off into the river might increase bacterial growth and consume the dissolved oxygen in the river with resultant decrease as it flows downstream.

Moreover, observation of Figure-5. Shows that the BOD mechanism peaked at "PZ" sampling point and lowest at "AB" sampling point. This fact is in agreement with previous research work on physicochemical assessment and water quality index[6] since the "AB" happens to be abattoir with active animal slaughter and their subsequent disposal of organic tissues into the river. This will equivalently increase bacterial growth that will rapidly deplete available oxygen. However, the BOD levels between the seasons showed no seasonal variation within each year, which might be due to active and regular discharge of organic pollutants from abattoir source throughout the biannual study. The BOD water quality index of the studied river can be graded under Class V; hence, the river is unsafe, unclean and unacceptable for public consumption, recreation, fish habitation and requires immediate pollution control strategies and regulations.

Statistical evaluations: From Table-3, it shows that during 2015 all the parameters (DO, BOD and COD, TDS and TSS) had their row (monthly) values such that $F_{critical}$ was less than F_{value}. This meant that the values obtained were significant. Hence, seasonal variation within months had influence over the biannual study especially in 2015 rain and Harmattan season. Also during 2014 study, the TSS, TDS and COD column values had all parameters wherein $F_{critical}$ was greater than F_{value}. This meant that the values obtained were not significant. Hence, the different sampling sites had minimal or negligible influence over the aforementioned parameters.

Finally, in 2014 season only TSS had both column and row values confirmed as not significant. However P_{value} was greater than α_{value}, hence error greater than 5% exists within data obtained from the different sampling sites. On the other hand, in 2015 season, TSS and BOD had both their column and row values confirmed as significant. Furthermore, in both cases their P_{value} was less than α_{value}. Hence, error less than 5% exists within data obtained from the different sampling sites. Consequently, among all parameters measured in 2014 and 2015, TSS and BOD data was determined to be statistically more accurate and precise than TDS, COD and DO.

Table-3: ANOVA interpretation of Aba River data.

	Parameter	Minimum	Maximum	F-Value	F-Critical	P-Value	Alpha	Interpretation
2014	TSS	35.21	60.37	1.729 Row 1.192 Column	2.866 Row 2.711 Column	0.1829 Row 0.3480 Column	0.05	P > α: significant Row: $F_{critical} > F_{value}$ = not significant Column: $F_{critical} > F_{value}$ = not significant
	TDS	52.01	68.91	9.686 Row 1.9019 Column	2.866 Row 2.711 Column	1.59 x 10^{-5} Row 0.139 Column	0.05	P < α: not significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} > F_{value}$ = not significant
2015	TSS	27.52	53.78	17.31 Row 2.766 Column	2.866 Row 2.711 Column	2.8 X 10^{-6} Row 0.00466 Column	0.05	P < α: not significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} < F_{value}$ = significant
	TDS	40.48	49.26	5.004 Row 0.7520 Column	2.866 Row 2.711 Column	0.00584 Row 0.5943 Column	0.05	P1 < α: not significant P2 > α: significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} > F_{value}$ = not significant
2014	DO	4.786	6.413	1.153 Row 11.52 Column	2.866 Row 2.711 Column	0.360 Row 2.454 Column	0.05	P > α: significant Row: $F_{critical} > F_{value}$ = not significant Column: $F_{critical} < F_{value}$ = significant
	BOD	49.13	68.01	3.719 Row 6.294 Column	2.866 Row 2.711 Column	0.0203 Row 0.00113 Column	0.05	P < α: not significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} < F_{value}$ = significant
	COD	144.1	227.4	54.83 Row 2.148 Column	2.866 Row 2.711 Column	1.6 $X10^{-9}$ Row 0.1012 Column	0.05	P1 < α: not significant P2 > α: significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} > F_{value}$ = not significant
2015	DO	3.884	7.407	75.65 Row 0.855 Column	2.866 Row 2.711 Column	8.7 X 10^{-12} Row 0.5276 Column	0.05	P1 < α: not significant P2 > α: significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} > F_{value}$ = not significant
	BOD	45.91	79.40	22.78 Row 2.933 Column	2.866 Row 2.711 Column	3.2 $X10^{-7}$ Row 0.00381 Colum	0.05	P1 < α: not significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} < F_{value}$ = significant
	COD	143.8	290.2	100.1 Row 1.951 Column	2.866 Row 2.711 Column	6.2 X 10^{-13} Row 0.1304 Column	0.05	P1 < α: not significant P2 > α: significant Row: $F_{critical} < F_{value}$ = significant Column: $F_{critical} > F_{value}$ = not significant

Conclusion

Research findings showed that a positive co-relationship existed between COD and BOD. While a negative correlation (inverse) existed with DO and any of BOD and COD. The sampling site "NB" is the most active pollution sampling points while UT was the least active pollution site. Both COD and BOD peaked at "NB" before decreasing in concentration. While the DO values peaked at "Both NB and PZ" sampling points before decreasing. Although, the TDS concentrations were below WHO, EU and APHA standards while the maximum values of TSS exceeded the APHA, EU, EPA and FME discharge limits, except WHO standards (exponential high at 500mg/L). Therefore the finale is that water quality index showed that the river is polluted largely and requires immediate control and preventive measures.

Acknowledgement
This study was supported and made possible by team of resilient researchers from UNIZIK and FUTO who dedicated themselves to a common goal. We also appreciate the primary Supervisors: Prof P.A.C Okoye and Prof. V.I.E Ajiwe for their unending inputs. No special funding was received for this research work.

Abbreviations (nomenclature): AB/A - Abattoir area, ANOVA - Analysis of variance, APHA - American Public Health Association, BOD -Biochemical Oxygen demand, COD - Chemical Oxygen Demand, DDW - Double Distilled Water, DO -Dissolved Oxygen, DS/D – Downstream, EU - European Union, EPA- Environmental Protection Agency, FME - Federal Ministry of Environment, FUTO - Federal University of Technology Owerri, Imo State, Nigeria. P.M.B 1526, NB/N - Nigerian Breweries area, PZ/P - Petterson Zechonics area, TDS - Total Dissolved Solute, TSS - Total Suspended Solid, UNIZIK - Nnamdi Azikiwe University, Awka, Anambra State. USEPA - United States Environmental Protection Agency, UT/U – Upstream, WHO - World Health Organization.

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