

MODELING IKPOBA RIVER WATER QUALITY USING PRINCIPAL COMPONENT ANALYSIS (PCA) METHOD AND WATER QUALITY INDEX

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Abstract — This study examined the effects of brewery wastewater on the quality of water in Ikpoba River which has experienced significant pollution over the years, with a view of determining the main pollutants in the river water. River water samples were collected from eight different sampling locations covering a total distance of 750 m: one sample from upstream at 150 m from the effluent discharge location, two samples from effluents discharge point, and five samples from the downstream location at 150 m interval. The samples were collected twice a month in March, May, and July 2014 during the period of intense activity of production. The physico-chemical analyses of the 25 selected parameters were analysed and values obtained were used to calculate the water quality index (WQI) of the river. The results indicated that Ikpoba River is severely polluted (WQI = 54.29792.89, in SN1, March, 2014) as a result of untreated brewery effluent. Principal Component Analysis (PCA) was applied to identify the parameter that contributes mainly to the pollution of the river. The result of the PCA further shows that the only reoccurring parameter is Copper. Therefore, the study concludes that Copper is the only component factor that influences the river water quality throughout the period under study. The study strongly recommends that any proposed treatment method must be targeted at the removal of copper in addition to other factors of high contributory effects.

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Keywords: effluent, pollution, brewery, water quality index, discharge

1.0 INTRODUCTION

With advancement in technology, the immediate environment bears the brunt of uncontrolled pollution associated with industrialization. The release of industrial wastewater has caused inevitable modification in the ecology and quality of the receiving stream [1, 2]. Recently, the challenge of municipal solid waste disposal and management of industrial effluent have been on the rise. The brewery and the malting industries have contributed greatly to this menace not only in the generation of large quantity of wastewater but the effluent is highly rich in organic contents [3]. The interest in environmental cleanliness alongside shortage of portable water which is in high demand is clear indication that water rates are bound to increase globally. This poses a fresh challenge to water resources and aquatic ecologist managers. Several methods have been developed to monitor/regulate the quality of wastewater discharged by effluent generating factories into streams [3].

The origin of these problems may be attributed to many sources and types of pollutants. Some pollutants may have indirect effects whilst substances normally not considered as pollutants may become so under special circumstances. Researchers have categorized water pollutants into eight namely; sediment pollution, sewage, organisms causing diseases, inorganic plant and organic compounds, and algae nutrients (e.g. Phosphorus and Nitrogen) [4]. Others are radioactive substances, inorganic chemicals, and thermal pollution. Apart from the discharge of specific pollutant in water, the construction of dams, reservoir and river diversion can also degrade water quality. The quality and amount of brewery wastewater can change significantly depending on the different production processes that take place inside the factory. These processes include, but not limited to the following: handling of raw materials, preparation of wort, fermenting, filtering, and packaging.

However, the volume of water utilized in each process differs considerably. Barley malting is the first stage in any brewing processes; it consists of grain steeping and germination under controlled relative humidity and temperature. Effluent generated in this stage is mainly steep water. Consequently, effluents are generated in many processes of plant operations. These operations are; wort dilution, fermented wort and beer spill, waste during spent grains separation, washing of fermentation tanks, keg filling, beer bottling and separation of yeast. Added to these wastes are the runoff from bottles & kegs washing and wastewater from tanks washing. The sources of these wastes maybe small or large, weak or strong, inconsistent or continuous generation which result in wide variations in pH, temperature, load, total volume and composition on a daily and even on hourly basis.

Many researchers have reported on water volume consumed and wastewater released in every production unit. The weight of pollutants generated in the malting house is within 3.5-4.5 kg of BOD for every ton of barley malted. In modern breweries, the value lies within 7.0-10.0 kg BOD for every cubic meter (m³) of beer. Water consumed varies in different breweries but usually lies within 4.0-30.0m³/m³ [5]. Brewery effluents are classified as medium to high strength organic wastewater. More so, the organic compounds in the brewery effluents are basically biodegradable as they contain sugar, fatty acid, starch, and ethanol. The BOD/COD ratio for fresh brewery effluents is quite high (usually between 0.6-0.7mg/l). This necessitates the treatment of brewery wastewater using biological process [6].

Brewery solids usually known as Total Suspended Solid (TSS) are mainly turb, wasted yeast, and grains. The pH of brewery wastewater is ascertained by the quantity and type of chemical used in the production units. Generally, the chemicals utilized are; phosphorous acid, caustic soda, and nitric acid. The quantity of phosphorous and nitrogen in brewery wastewater is a function of raw material handling and the amount of waste yeast available in the wastewater. In addition, the phosphorous containing chemicals can manipulate the level of phosphorous in the brewery effluent [7, 8, 9]. The discharge effluent standards for brewery industries have to comply with the environmental legislations. Effluent discharges into municipal sewer are less stringent compared to effluent discharge into sensitive receiving surface water bodies, such as rivers and lakes. Organic compounds removal from effluent is essential in preventing anaerobic condition from occurring in the recipient water bodies. Unpleasant odour and aesthetic problems emerge due to anaerobic condition of receiving waters [10]. To avoid the formation of algae bloom in the recipient streams, nutrients like nitrogen (N) and phosphorous (P) must be expunged. Thus, this study evaluated the effects of brewery effluents on the water quality of Ikpoba River, which receives discharge from some breweries within the basin.

2.0 MATERIALS AND METHODS

Two brewery (Bendel Brewery and Guinness Nigeria plc) industries are sited within Oregbeni community of Benin City, Edo State. At the time of sample collection, only Guinness Nigeria plc was in full operation. Oregbeni community has borders with Ikpoba River. The River is a fourth order stream and it passes through Benin City, in Southern part of Nigeria. The headwater is located within latitude 6.5°N and longitude 5-8°E and it comes from north-western direction in Benin City and flows southwards into the city [11]. The river passes through thick rain forests where allochthonous infusions of organic matters from the border vegetation are obtained by runoff from soil surface. Benin Basin system which is the third largest in Nigeria, receives runoff from Ikpoba River. The river is the major source of drinking water and other domestic uses for the downstream settlers who also use it for fishing. Ikpoba River collects different forms of wastes from agricultural deposits, domestic, industrial, and commercial sources. These refuges bring toxic, microorganisms, organic and inorganic matters into the river. The waste products from the various breweries activities which usually have large wastewater volumes are transported through underground channels of about 2.5km and emptied directly into Ikpoba River [12]. Production and marketing of various brands of beer is the sole activity in these breweries. Effluent in variant compositions but with a common characteristic of

high organic matters is generated in the course of production. This is responsible for the growth of vegetation within the wastewater discharge location. The geology consists of crystalline basement rocks in the hilly and dissected zone in the north, followed southward by residual lateritic soils of the well-drained dry lands in the North. Continental deposits further south consist of Benin formation. The flood plains further inland are composed of medium-coarse point bar sands and clayey back swamp deposits. The river is located within the rain forest zone of Nigeria with mean annual rainfall of range 1500mm to 2100mm and mean monthly temperature varying from 23°C to 27°C. The land mass in the area is undulating with intermittent valleys and flat terrains from the southern part of the state with height above sea level ranging from 15m in the south to 300m in the north. The vegetation is predominantly guinea savannah with little of forest and scrub vegetation. Ikpoba River is one of the five streams that drain Benin City covering drainage area of over 800 km².

3.0 STUDY DESIGN

This study was carried out to assess the physicochemical quality of the effluent from a point source before entering the river and at point of release; the quality of the river water at both upstream and downstream locations was evaluated. The entire river length in the location was partitioned into two regions depending on the locations of release of wastewater into the river. The regions were basically upstream and downstream regions. The partition line was placed at the point of wastewater release location and was tagged as effluent release point. About 750 m length of the river was monitored downstream while 150 m upstream from this point was also monitored. Water samples were collected for analysis within these two extremes.

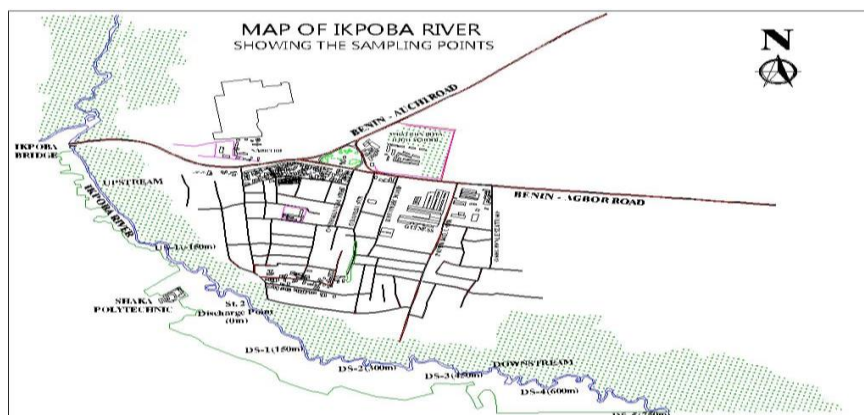


Figure 1: Map of Ikpoba River with sampling locations

3.1 SAMPLING POINTS AND GEO-LOCATIONS

The upstream and downstream points of the wastewater discharge point where mixing was done was based on established geo locations. Table 1 shows sampling locations within the river channel.

Table 1: Summary of geo-locations for sampling points

Sample Code	Northing	Easting	Elevation
Point source of effluent (SN1)	N06°20' 016"	E005°39'880"	27m
Discharge point 0m (SN2)	N06°20'019"	E005°39'870"	28m
150m US-1 (SN3)	N06°20' 024"	E005°39'829"	28m
150m DS 1 (SN4)	N06°20'004"	E005°39'894"	
300m DS 2 (SN5)	N06°20'019"	E005°39'918"	
450m DS 3 (SN6)	N06°20'034"	E005°39'942"	31m
600m DS 4 (SN7)	N06°20'049"	E005°39'966"	
750m DS 5 (SN8)	N06°20'064"	E005°39'900"	

Note: SN is Station Number, US is Upstream while DS is Downstream

3.2 SAMPLE RECOVERY AND PHYSICO-CHEMICAL ANALYSES OF WATER SAMPLES

River water samples were collected bimonthly in March, May and July 2014 at eight sampling locations; this covers the discharge point, upstream and downstream (one sample from upstream at 150 m from the effluent discharge location, two samples from effluents discharge point and five samples from the downstream location at 150 m interval). This was used in monitoring the composition of waste discharged, the quality of the water at release (discharge) location and downstream points as well as variations produced by seasonal water cycle within the study duration (March - July), a transition from the dry spell to the wet season. Sampling was conducted by washing the containers using the river water; thereafter the samples were collected and stored in cooler containing ice (ice chest). Additional samples were collected for analysis of heavy metal and stored in clean plastic containers with 3ml analar grade nitric acid per litre sample. The 25 physico-chemical parameters analysed were sodium, salinity, turbidity, electrical total soluble solids, total dissolved solids, biological oxygen demand, copper, chemical oxygen demand, colour, temperature, concentration of bicarbonate, chloride, phosphates, ammonia, nitrate, nitrite, nitrite iron, magnesium, calcium, cadmium, dissolved oxygen, conductivity, lead, pH, nickel, vanadium, chromium and total hydrocarbon. Escheria coliform was also measured but the result obtained from the measurement was not used in the physico-chemical analysis.

The water samples were then subjected to full laboratory analysis in order to determine their physico-chemical properties. Some of the methods employed in the analysis are described below:

3.2.1 TURBIDITY MEASUREMENT

The amount of colloidal and residual suspended matter present in the water samples was determined using the Jenway 6035 Turbidimeter.

3.2.2 HYDROGEN ION CONCENTRATION (pH)

The hydrogen ion concentration (pH) of the water samples was determined using a standard laboratory digital micro-processor pH meter; Hanna pH 210 model.

3.2.3 DISSOLVED OXYGEN CONTENT (DO)

The dissolved oxygen content (DO) of the water samples was measured using a standard laboratory sized digital dissolved oxygen analyzer model: DO – 5509.

3.2.4 CONDUCTIVITY MEASUREMENT

The conductivity of the water samples was determined using a digital water/sand quality test kit model SN2209

3.2.5 TOTAL DISSOLVED SOLIDS (TDS)

The amount of total dissolved solids (tds) present in the different water samples was determined using a digital water/sand quality test kit model SN2209

3.2.6 HEAVY METAL DETERMINATION

The concentration of heavy metals present in the different water samples was determined using Atomic Adsorption Spectrophotometer (AAS). (SOLAAR 969 UNICAM SERIES, using air acetylene flame).

3.2.7 TEMPERATURE

Temperature was noted by thermometric method at the sampling using portable calibrated Mercury thermometer in the Multi-Parameter Meter.

3.2.8 ELECTRICAL CONDUCTIVITY

The ability of the aqueous solution to convey current was determined using the Conductivity Meter in the Multi-Parameter Meter.

3.2.9 BIOLOGICAL OXYGEN DEMAND (BOD)

The samples were incubated for 5 days at 20°C in the dark, the reduction in dissolved oxygen concentration during the incubation period yields a measure of the BOD.

3.2.10 COLOUR

Colour was determined by using GENESYS-10VIS Spectrophotometer, based on the difference between the sample colour and the water colour.

Colour of water in mg/l PtCo = (Sample Colour – Water Colour)

3.3 STATISTICAL ANALYSIS OF DATA

To assess the variation of the overall water quality along the river, Water Quality Index (WQI) modelling was done on twenty-five physico chemical properties of the water samples in March, May, and July, 2014. WQI was computed for each sampling period using the following approach;

3.3.1 DETERMINATION OF WEIGHTAGE

In calculating WQI, the Weightage of each of the parameters identified was first ascertained. Parameters with higher allowable limit are less toxic because they cannot change surface water quality even when they are in large amount. Therefore, the weightage of tested parameters has an inverse relationship with the allowable limit. Hence

$$W_n = \frac{K}{S_n} \quad (1)$$

where:

W_n = Tested Parameter Unit Weight

S_n = WHO Standard Values

K = Constant of proportionality

$$K = \frac{1}{\sum_{i=1}^s \frac{1}{S_n}} \quad (2)$$

3.3.2 QUALITY RATING COMPUTATION

Rating scale was assembled for set of values of each parameter. This rating ranged from 0 – 100 and was shared in intervals of five. The rating $q_n = 0$ indicates severe pollution (the tested parameter indices surpasses the maximum allowable limit. Conversely, $q_n = 100$ is an indication that parameter indices available in the water has desirable values. Other ratings ($q_n = 40$, $q_n = 60$ and $q_n = 80$) are within these extremes. These values represent excessive pollution, moderate pollution and slightly less pollution respectively. This is the modified version of the rating scale; it is calculated as follows [13, 14]:

$$q_n = \frac{100(V_n - V_{io})}{(S_n - V_{io})} \quad (3)$$

where:

q_n = Quality rating or sun index

V_n = Test result for each parameter tested

S_n = Standard value of each parameter

V_{io} = ideal value of selected parameters tested (in pure water $V_{io} = 0$ for all parameters tested except pH and dissolved oxygen which is 7.0 and 14.6 respectively).

The resulting value is multiplied by a weightage factor which has significance to the water quality. The resulting sums are added to obtain one WQI for the water. It is a mathematical approach for the calculation of a unit number from various test results. The Water Quality Index calculated from the results, is a representation of the level of water quality in any given water body. The steps below were followed in evaluation of WQI in the river:

- i. The weightage unit (W_n) were determined for all tested parameters and added to get $\sum W_n$
- ii. The quality rating of all parameters tested were added to get $\sum q_n$
- iii. The index $W_n \cdot q_n$ was calculated for each parameter tested and summed up to obtain $\sum W_n \cdot q_n$
- iv. Mass balance equation was used to compute WQI for each water sample $\frac{\sum W_n \cdot q_n}{W_n}$
- v. Water Quality Index (WQI) = 100-Z was used to represent the level of water quality.

Also, factor analysis using Principal Component Analysis (PCA) for the months of March, May and July 2014 was used to assess that all the water quality parameters used for the analysis contributes reasonably to the overall variation in the quality of the river water. The analysis was carried out using statistical software, SPSS version 16.0 (statistical package for the social sciences).

4.0 DISCUSSION OF RESULTS

The physico-chemical analysis results of the 25 selected parameters are presented in Table 2 and were compared with WHO and Federal ministry of Environment Standards. WQI was computed from the values in Table 2; the results indicate a serious level of pollution occasioned by the discharge of poorly treated brewery effluent into Ikpoba River. WQI computed for station one in March, 2014 was as high as - 5429792.89; this is an indication that brewery effluent is highly polluted and when released in its raw state into the river, the consequences is high degree of water pollution as experienced in all the stations from which water samples were collected. The bar chart showing water quality index (WQI) with sampling stations for the period under investigation are shown in Figures 2, 3 and 4 respectively.

Pollution levels were observed to be higher at the point source of brewery effluent and at the discharge point compared to upstream and downstream locations of the Ikpoba River. This is deduced from the levels of the water quality parameter at the point source of effluent being higher than at the discharge points and in turn the discharge points correspondingly higher than the upstream and downstream locations respectively. The brewery effluent at point source had high values of COD, EC, temperature, TSS, TDS, Cl^- , SO_4 , and HCO_3^- which experienced considerable reduction at the discharge point where the effluent mixes with the river as a result of dilution principle. The values at the upstream and downstream locations were lower as a result of dilution. For TSS, a significant rise was noticed throughout the sampling periods from the upstream to the downstream locations. This can be explained from the movement of brewery effluents with high TSS levels into the river which experiences differential sedimentation as we move down the reach of the river. The levels of TSS during the rainy months (May and July, 2014) were generally lower compared to the dry month of March, 2014; this is attributable to the solubility of the solids discharged during rainy season.

Table 2: Comparison of the overall range of the water quality of Ikpoba River (March –July, 2014) with some water quality standards

Parameters	Range of parameter values Ikpoba river	Water quality standards	
		WHO	FMNEV
Temperature (°C)	25.4 – 37.1		<40
pH	6.2 -10.6	7-8.5	6-9
EC ($\mu\text{S}/\text{cm}$)	30 -1654		400
TDS (mg/l)	20 – 827	100	2000
TSS (mg/l)	5.2 -142.5		30
Turbidity (NTU)	8 – 71		
Cl^- (mg/l)	20.7 – 141.8		200
PO_3^{4-} (mg/l)	0.15 – 9.40		
NO_3^- (mg/l)	0.02 – 2.63	50	
Cd (mg/l)	0.002 – 0.102	0.003	<1
Zn (mg/l)	0.06 – 0.14	0.01	<1
Pb (mg/l)	0.0003 – 0.103	0.01	<1
Ni (mg/l)	0.0003 – 0.213	0.02	
Cu (mg/l)	0.001 – 0.18		
Ca^{2+} (mg/l)	0.45 – 14.41		
Salinity (g/l)	0.0018 – 0.578		
DO (mg/l)	4.0 – 6.90		
BOD_5 (mg/l)	2.0 – 5.7		50
COD (mg/l)	28.8 – 242.4	10-20	150
THC	0.46 -5.70		
Mg(mg/l)	0.005 – 9.51		
Na (mg/l)	0.50 – 53.10		
SO_4	0.68 – 34.75		
V(mg/l)	0.003 – 0.27		
Fe(mg/l)	0.59 -6.74		

The levels of these parameters at point source when compared with the discharge standards as stated by WHO; pH, COD, turbidity, TSS and PO_3^{4-} were found to be much higher than discharge standard. At the upstream and downstream locations, there was reduction in the parameters values which is due to dilution. The pH values of the brewery effluent at point source range from 9.8 – 10.6 which were the highest compared to the discharge point which range from 6.9 – 8.6. The high pH values of the brewery effluent at the point source which exceeded the WHO limit are not surprising since the brewery process requires use of disinfectants and batch discharging of caustic cleaning solutions or basic detergent for the cleaning stage. At

the discharge point, pH values were within the permissible limits of 6.5 – 9.5 by WHO discharge standards. The upstream pH values were slightly higher than the corresponding downstream locations, however the average pH values of the upstream and downstream stations of the Ikpoba River during the rainy months (May and July, 2014) were higher than the corresponding end of dry season.

At the discharge point of brewery effluent, dissolved oxygen levels were much lower than corresponding levels for either upstream or downstream sampling points with a much higher chemical oxygen demand than corresponding levels for both upstream and downstream locations. The DO levels at the point source of brewery effluent ranged from 4.0 to 5.0mg/l and the discharge point ranged from 4.5 to 5.5mg/l. the DO levels at the upstream ranged from 5.2 – 6.5mg/l while the average DO of downstream location is 6.2mg/l. The DO values obtained at the point source is an indication that the brewery effluents contain a high organic load of matter that could have consumed the available dissolved oxygen. The COD at the point source ranged from 196.0 to 242.4mg/l while it ranged 171.2-182.2mg/l at the discharge, upstream and downstream points; indicating that the brewery effluent at the point source would require more oxygen due to high oxygen demanding waste than at the discharge, upstream and downstream points. The average level of ammonium nitrogen in the brewery effluent at point source and the discharge point during transition from dry to rainy seasons ranged from 0.98 to 2.63mg/l and 0.12 to 1.60mg/l respectively. The presence of ammonia concentrations in the effluent has its origin from the proteins and chitins load contained in the brewery waste [15]. Apart from the high organic content of brewery effluent, spent wash generated from the fermentation step also contains nutrients in the form nitrogen. Spent wash is the dark brown distillery wastewater generated during the fermentation step of beer production [15].

The overall turbidity of the brewery effluent ranging from 17-71NTU indicates the quantity of TSS in it, particularly at such high solid concentration (142.5mg/l) in the dry month of March. Turbidity does not directly correlate with suspended concentration because colour can sometimes interfere with its measurement; none the less it affords a relative indication of suspended solid levels [16]. The salinity level of the river at upstream locations during the end of the dry season of March 2014 was 0.02g/l, and 0.027g/l and 0.036g/l during the rainy season of May and July, 2014. The salinity level was raised to 0.027g/l, 0.032g/l and 0.045g/l at the downstream locations during both seasons. The observed increases were due to flow of brewery effluent discharge with high alkalinity levels at all instances with corresponding drops from downstream locations resulting from dilution along the reach of the river. Zn, Pb, Cd, and Ph in all the locations of investigations far exceeded the WHO allowable limits during the period of study. Environmental concern associated with the Ph, Cd and Pb are centred on the ecological simulation of algae growth in the river to water poisoning and undesirable depletion of DO in the river [17, 18].

Figures 2, 3 and 4 revealed that higher level of water pollution was experienced in the month of March (dry season) as compared to May and July (wet season). The lower level of pollution experienced in the month of May and July is due completely to the high volume of water present in the river occasioned by seasonal variation (raining season). The high volume of water tends to dilute the concentration of the effluent as the distance away from the point source of pollution increases [19, 20]. Also, the high volume of water promotes increased steady rate of flow and boost the self-replenishing and purification effects of the river body [21, 22].

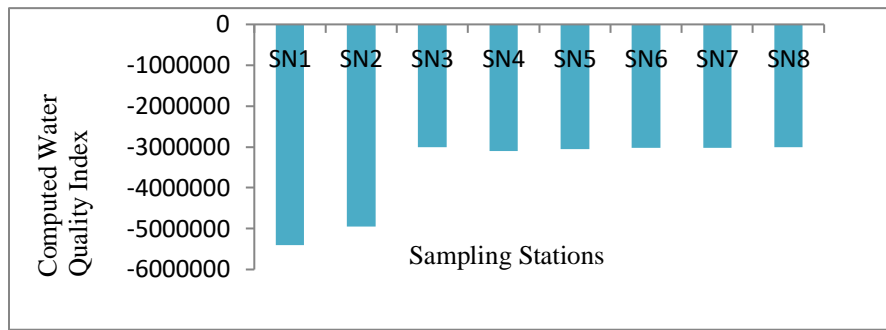


Figure 2 Variation of WQI with sampling stations for the month of March, 2014

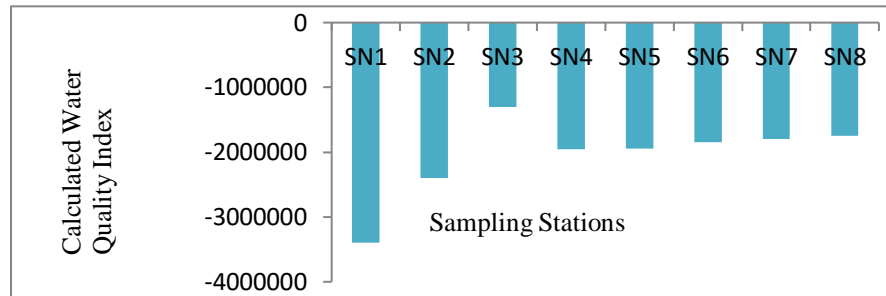


Figure 3 Variation of water quality index with sampling stations for the month of May, 2014

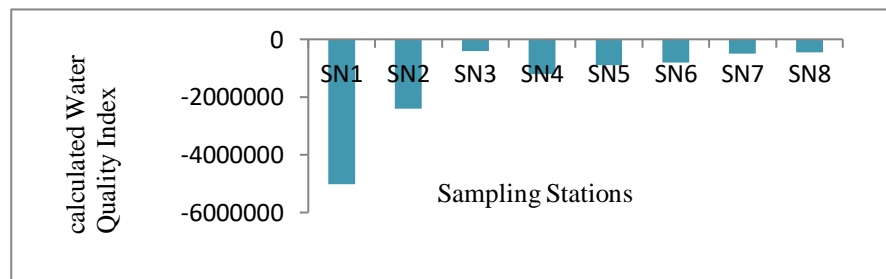


Figure 4 Variation of water quality index with sampling stations for the month of July, 2014

Since the overall status of the river is characterized by high level of pollution occasioned by the discharge of poorly treated brewery effluent, then it is important to establish the contributions of each physico-chemical parameters of the river water that was investigated. This is to distinguish the parameters that promote high level of contamination from those that contribute minimal pollution. This was achieved by subjecting the test parameters (25) to statistical analysis using Principal Component Analysis (PCA). This method of PCA was employed to perform the analysis and the anti-image correlation matrix was used to ascertain the viability of factors analysis in explaining the correlation of the physico-chemical properties. The results showed that the entire off-diagonal matrix is less than unity (one) hence the factor analysis is adequate for the analysis. PCA was also utilized in extraction analysis; this is to determine how well the factors explain the variation in the physico-chemical properties with distance along the river using the total variance. The extraction solution using PCA reveals that the 25 physico-chemical properties can only be grouped into three component matrix as seen in the solution of the initial eigenvalues. The results are show in Tables 3-5.

Table 3: Extraction using principal component analysis (March, 2014)

Component	Total Variance Explained								
	Initial Eigenvalues			Extraction sum of squared loadings			Rotation sum of squared loadings		
	Total	% Var.	% Cum.	Total	% Var.	% Cum.	Total	% Var.	% Cum.
1	20.92	83.67	83.67	20.92	83.67	83.67	10.92	43.68	43.68
2	2.08	8.34	92.01	2.08	8.34	92.00	8.02	32.09	75.76
3	1.00	4.01	96.01	1.00	4.01	96.01	5.06	20.25	96.01
4	0.82	3.27	99.28						
5	0.17	0.69	99.97						
6	0.01	0.02	99.99						
7	0.002	0.01	100.00						
8	3E-15	1E-14	100.00						
9	9E-16	4E-15	100.00						
10	8E-16	3E-15	100.00						
11	6E-16	2E-15	100.00						
12	5E-16	2E-15	100.00						
13	4E-16	1E-15	100.00						
14	3E-16	1E-15	100.00						
15	2E-16	1E-15	100.00						
16	1E-16	5E-16	100.00						
17	5E-17	2E-16	100.00						
18	-3E-17	-1E-16	100.00						
19	-2E-16	-7E-16	100.00						
20	-3E-16	-9E-16	100.00						
21	-4E-16	-1E-15	100.00						
22	-5E-16	-2E-15	100.00						
23	6E-16	-2E-15	100.00						
24	-7E-16	-3E-15	100.00						
25	-9E-16	-4E-15	100.00						

Extraction Method: Principal Component Analysis

Table 4: Extraction using principal component analysis (May, 2014)

Component	Total Variance Explained								
	Initial Eigenvalues			Extraction sum of squared loadings			Rotation sum of squared loadings		
	Total	% Var.	% Cum.	Total	% Var.	% Cum.	Total	% Var.	% Cum.
1	21.40	85.59	85.59	21.40	85.59	85.59	16.05	64.18	64.18
2	1.60	6.37	91.96	1.59	6.37	91.96	6.38	25.54	89.71
3	1.08	4.33	96.29	1.08	4.33	96.29	1.64	6.57	96.29
4	0.79	3.15	99.44						
5	0.13	0.52	99.961						
6	0.08	0.03	99.99						
7	0.02	0.01	100.00						
8	1.7E-15	6.9E-15	100.00						
9	8.4E-16	3.4E-15	100.00						
10	8.7E-16	2.8E-15	100.00						
11	4.8E16	1.9E-15	100.00						
12	4.2E-16	1.7E-15	100.00						
13	2.4E-16	9.7E-16	100.00						
14	1.1E-16	4.3E-16	100.00						
15	3.2E-17	1.3E-16	100.00						
16	-3.3E-17	1.3E-16	100.00						
17	-8.4E-17	-3.4E-16	100.00						
18	-1.3E-16	-5.2E-16	100.00						
19	-2.7E-16	-1.1E-15	100.00						
20	-4.1E-16	-1.6E-15	100.00						
21	-5.5E-16	-2.2E-15	100.00						

22	-5.7E-16	-2.3E-15	100.00
23	-6.8E-16	-2.7E-15	100.00
24	-7.1E-16	-2.8E-15	100.00
25	-1.5E-15	-6.1E-15	100.00

Extraction Method: Principal Component Analysis

Factors with eigenvalues greater than one represent the number of factors needed to describe the underlying dimensions of the effect of brewery effluents on the river water quality. These are the factors that contribute adequate amount to the variation in the physico-chemical properties of the water samples collected at different points along the river. The eigenvalues are used as a cut off in factors analysis since it is the sum of the squared factors loadings of all variables. Factors with eigenvalues less than one means that such factors such factor do not have any influence on the overall issue under study. The results obtained from the factor analysis are shown in Figures 5, 6 and 7 indicates that there are three (3) component factors with eigenvalues greater than unity. These are the component factors with the highest influence on the river quality.

Table 5: Extraction using principal component analysis (July, 2014)

Component	Total Variance Explained								
	Initial Eigenvalues			Extraction sum of squared loadings			Rotation sum of squared loadings		
	Total	% Var.	% Cum.	Total	% Var.	% Cum.	Total	% Var.	% Cum.
1	20.26	81.06	81.06	20.26	81.06	81.06	13.84	55.37	55.37
2	2.77	11.02	92.08	2.76	11.02	92.08	8.33	33.30	8.66
3	1.43	5.71	97.79	1.43	5.71	97.79	2.28	9.13	97.79
4	0.42	1.67	99.46						
5	0.13	0.51	99.97						
6	0.001	0.03	99.99						
7	0.002	0.006	100.00						
8	1.1E-15	4.5E-15	100.00						
9	8.2E-16	3.3E-15	100.00						
10	6.3E-16	2.5E-15	100.00						
11	5.6E-16	2.2E-15	100.00						
12	4.2E-16	1.7E-15	100.00						
13	3.3E-16	1.3E-15	100.00						
14	2.0E-16	8.1E-16	100.00						
15	1.3E-16	5.2E-16	100.00						
16	6.4E-17	2.6E-16	100.00						
17	-4.9E-17	-2.0E-16	100.00						
18	-2.0E-16	-8.1E-16	100.00						
19	-2.8E-16	-1.1E-15	100.00						
20	-3.0E-16	-1.2E-15	100.00						
21	-4.3E-16	-1.7E-15	100.00						
22	-5.6E-16	-2.3E-15	100.00						
23	-8.4E-16	-3.6E-15	100.00						
24	-1.0E-15	-4.1E-15	100.00						
25	-2.9E-15	-1.2E-15	100.00						

Extraction Method: Principal Component Analysis

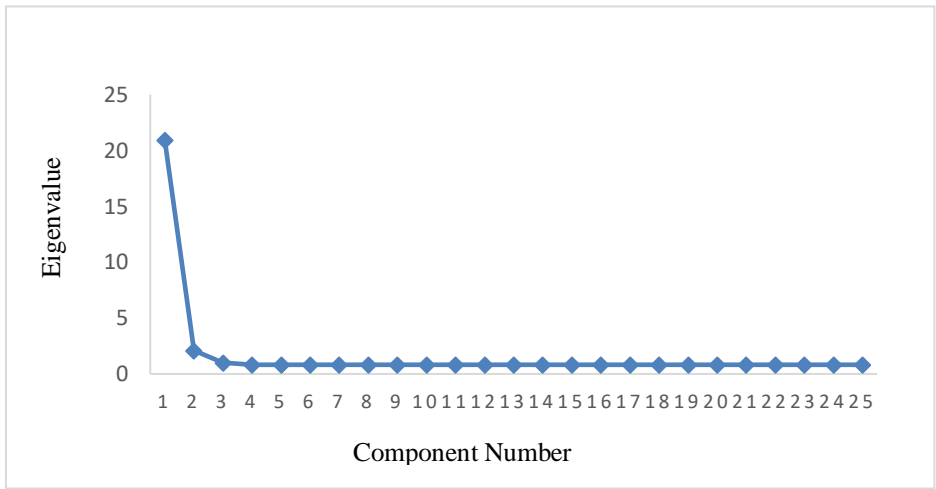


Figure 5: Screen plot showing component factors with highest influence (March, 2014)

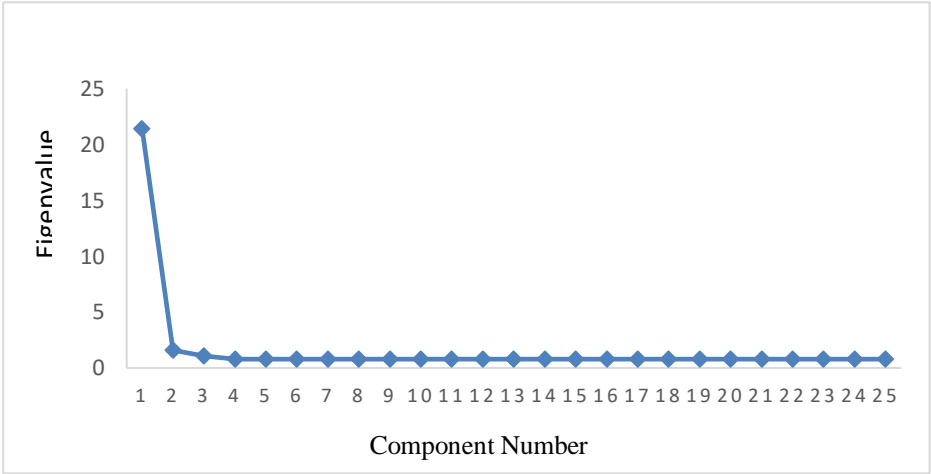


Figure 6: Scree plot showing component factors with highest influence (May, 2014)

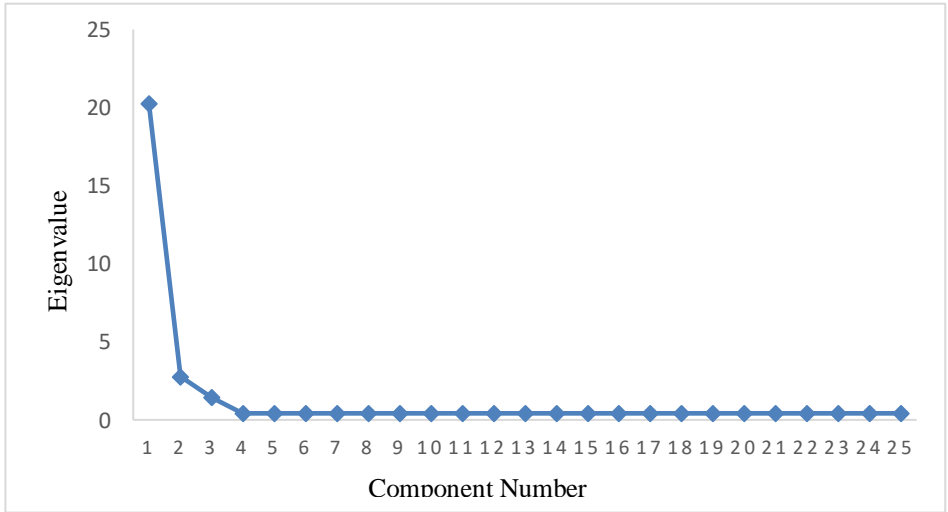


Figure 7: Scree plot showing component factors with highest influence (July, 2014)

From the results of the scree plots, it is clear that three component factors possess very strong influence on the overall quality of the river water. To find the variables that make up each of the component factors, factor loadings was checked and the best favoured variable was selected for component factors. The results of the factor loadings are presented in Table 6, 7 and 8.

Table 6: Makeup of the component factors (March, 2014)

Variable Code	Variables		Component Factors		
	Variable Name		1	2	3
X ₁	pH		0.980		
X ₂	Nitrate		0.904		
X ₃	Electrical Conductivity		0.924		
X ₄	Turbidity		0.980		
X ₅	Dissolved Oxygen			0.648	
X ₆	TDS		0.925		
X ₇	Sodium		0.985		
X ₈	Lead		0.922		
X ₉	Sulphates		0.991		
X ₁₀	Zinc		0.898		
X ₁₁	Copper		0.987		
X ₁₂	Chloride		0.995		
X ₁₃	Iron		0.933		
X ₁₄	BOD ₅		0.576		
X ₁₅	COD		0.980		
X ₁₆	HCO ₃		0.983		
X ₁₇	TSS		0.757		
X ₁₈	Ammonia		0.882		
X ₁₉	Nitrite		0.946		
X ₂₀	Cadmium		0.938		
X ₂₁	Nickel		0.956		
X ₂₂	THC		0.949		
X ₂₃	Phosphate		0.970		
X ₂₄	Magnesium		0.759		
X ₂₅	Calcium		0.907		

The results presented in Tables 6 reveals that the first component factor is most highly correlated with; pH, nitrates, EC, turbidity, TDS, sodium, lead, sulphate, zinc, copper, chlorine, iron, BOD, COD, bicarbonate, TSS, ammonia, nitrite, cadmium, nickel, THC, phosphate, magnesium and calcium. Chloride has the strongest influence with a magnitude of 0.995. The second component is most highly correlated with dissolved oxygen. The results also show that chloride, COD, sulphate, copper, sodium, and carbonate are the most important variables affecting the quality of the river water in March, 2014.

Table 7: Makeup of the component factors (May, 2014)

Variable Code	Variables Variable Name	Component Factors		
		1	2	3
X ₁	pH	0.963		
X ₂	Nitrate	0.991		
X ₃	Electrical Conductivity	0.946		
X ₄	Turbidity	0.962		
X ₅	Dissolved Oxygen		0.531	
X ₆	TDS	0.944		
X ₇	Sodium	0.982		
X ₈	Lead	0.986		
X ₉	Sulphates	0.975		
X ₁₀	Zinc	0.987		
X ₁₁	Copper	0.980		
X ₁₂	Chloride	0.895		
X ₁₃	Iron	0.942		
X ₁₄	BOD ₅		0.725	
X ₁₅	COD	0.936		
X ₁₆	HCO ₃	0.996		
X ₁₇	TSS		0.572	
X ₁₈	Ammonia	0.991		
X ₁₉	Nitrite	0.993		
X ₂₀	Cadmium	0.918		
X ₂₁	Nickel	0.921		
X ₂₂	THC	0.997		
X ₂₃	Phosphate	0.938		
X ₂₄	Magnesium	0.986		
X ₂₅	Calcium	0.953		

In Table 7, it was observed that the first component factor is most likely correlated with; pH, nitrate, EC, turbidity, TDS, sodium, lead, sulphates, zinc, copper, chloride, iron, COD, bicarbonate, ammonia, nitrite, cadmium, nickel, THC, phosphate, magnesium and calcium. Total Hydrogen Content (THC) has the strongest influence with a magnitude of 0.997. The second component factor is most likely to correlate with Total Suspended Solids (TSS), dissolved oxygen and Biochemical Oxygen Demand (BOD). It was also noticed that nitrate, sodium, lead, copper, zinc, ammonia, nitrite, magnesium, THC, and carbonate are the most important variables affecting the quality of the river water in May, 2014.

Table 8 shows that the first component factor is most likely correlated with pH, nitrate, EC, turbidity, TDS, ammonia, nitrite, cadmium, nickel, THC, phosphate, magnesium, and calcium. The second component factor is most highly correlated with BOD. It was also observed from the results that dissolved oxygen do not have any influence on the quality of water in the month of July, 2014. The most important variables affecting the quality of the water in the river in July, 2014 are; turbidity, zinc, copper and phosphate.

Table 8: Makeup of the component factors (July, 2014)

Variable Code	Variables Variable Name	Component Factors		
		1	2	3
X ₁	pH	0.750		
X ₂	Nitrate	0.831		
X ₃	Electrical Conductivity	0.905		
X ₄	Turbidity	0.987		
X ₅	Dissolved Oxygen			
X ₆	TDS	0.909		
X ₇	Sodium	0.976		
X ₈	Lead	0.975		
X ₉	Sulphates	0.946		
X ₁₀	Zinc	0.992		
X ₁₁	Copper	0.991		
X ₁₂	Chloride	0.939		
X ₁₃	Iron	0.697		
X ₁₄	BOD ₅		0.880	
X ₁₅	COD	0.954		
X ₁₆	HCO ₃	0.979		
X ₁₇	TSS	0.652		
X ₁₈	Ammonia	0.978		
X ₁₉	Nitrite	0.863		
X ₂₀	Cadmium	0.923		
X ₂₁	Nickel	0.880		
X ₂₂	THC	0.960		
X ₂₃	Phosphate	0.996		
X ₂₄	Magnesium	0.925		
X ₂₅	Calcium	0.956		

Evaluation of the results in Tables 6-8 shows that the only reoccurring parameter is copper hence it is concluded that copper is the only component factor that influences the river water quality throughout the period under study. Therefore, it is strongly recommended that any proposed treatment method must be targeted at the removal of copper in addition to other factors of high contributory effects.

5.0 CONCLUSION AND RECOMMENDATIONS

This study has shown the effects of brewery wastewater on water quality of Ikpoba River and its vulnerability to pollution owing to the fact that it serves as a receptacle for receiving brewery effluent with poor quality that failed to meet some of the minimum discharge requirements for wastewater discharge into rivers/streams (Table 2). The pH, COD, turbidity, Pb, Cu, Zn, BOD, COD, Ph, DO and TSS of Ikpoba river raw effluents were not within tolerable limits in comparison to standard effluent discharge requirements set by WHO and European discharge standards (see Table 2). The WQI calculated for the eight (8) different stations revealed severe pollution during the period of study. WQI calculated in March, 2014 ranged from -5200000 in SN1 to 2980000 in SN3; in May, 2014, WQI calculated was within the range of -5000000 in SN1 to -500000 in SN3. A similar result was obtained in July, 2014 as WQI values ranged from -3700000 in SN1 to 1200000 in SN3. Discharge locations and point source of waste had severe pollution while upstream locations were least polluted. Principal Component Analysis carried out on the selected parameter revealed copper as the only recurring parameter hence copper is the only component factor that triggers other parameters beyond tolerable limits. This indicates inefficient effluent treatment in the breweries hence there is heavy organic load from these waste on the river. In view of the above results and conclusion, an efficient water conservation and effluent management system should be designed by Guinness Nigeria plc to improve the water quality

of Ikpoba River at discharge and downstream locations. This study therefore recommends the utilization of Activated carbon adsorption column in the treatment of brewery wastewater due to its efficiency in heavy metal removal from brewery effluent.

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