SSRG International Journal of Civil Engineering
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V7I3P105

Volume 7 Issue 3, 25-40, March 2020

The Study of the Depletion of Dissolved Oxygen InWoji/Okujagu River

Owor, A. Alexander.[1] Benedicta. U. Dike[2] and J.C.Osuagu[3]

[1, 2, 3]*(Federal University of Technology, Owerri, Imo State, Nigeria)*

Received Date: 28 February 2020
Revised Date: 31 March 2020
Accepted Date: 04 April 2020

Abstract
This work presents the depletion of dissolved Oxygen in Woji/Okujagu River in Port Harcourt Local Government Area of Rivers State Nigeria. The study was carried out between February 2017 (dry season) and August 2017 (wet season). The sampling exercise was done on six (6) selected stations (stations A, B, C, D, E, and F) along the river located at progressive distances 200m upstream and downstream from the point of effluent discharge. Sampling was done three times during the dry season (February) and during the wet season (August) 2017. The physical and chemical properties of the river samples such as temperature, Total Suspended Solids (TSS), Electrical Conductivity (EC), pH, Nitrates, Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO) were analyzed using standard methods. The parameters were then compared to ascertain their conformity with national and international standards set by the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA) and the World Health Organization (WHO).

Further analysis was carried out by applying an extended version of Thomas slope and O'Connor reaeration and Streeter-Phelps models to determine the depletion of dissolved oxygen in the river by the decomposition characteristics of the discharged effluents. The results of the analysis showed that the temperature ranged from 25.4º - 29.5ºC, TSS ranged from 145.6 – 484.4 mg/L, EC ranged from 422.7 – 982.2 μS/cm, pH ranged from 6.0 – 7.3, Nitrates ranged from 12.5 – 97.3 mg/L, BOD ranged from 22.5 – 75.2 mg/L and DO ranged from 2.2 – 6.5 mg/L. The only pH was within the recommended NESREA and WHO standards. The pollution index for all the stations was 2.7081. The critical time, t_c, was 6250 sec (0.0353 days). Deoxygenation constant, $K_d$and ultimate BOD, L_o were 0.744 and 79.2 mg/l, respectively. The reaeration constant, K_r, was 0.0282. The values of DO obtained from laboratory analysis were plotted against time. The DO curve generated showed that the minimum DO level of the river is 2.7mg/l. From the curve, the measured and simulated DO showed that the DO reduction rate tends to be greater than the self-purification rate, which can contribute greatly to the degradation of the quality of the river ecosystem and human/aquatic life. Therefore, it is recommended that the relevant authorities embark on regular monitoring activities of receiving rivers in Rivers State to ensure the human and aquatic population's safety and the environment.

Keywords: *Effluent discharge, river pollution, physiochemical parameters, dissolved oxygen, models.*

I. INTRODUCTION

Like rivers and streams, water bodies are the major mediums for the discharge of waste effluents from municipal, agricultural, and industrial activities. These effluents can pollute and change the accepting water body (Kanu and Achi, 2011). The alteration of aquatic ecological systems due to the discharge of solids, liquids, or gaseous substances into water bodies can cause damage to the nature of the water bodies and public health. This process is otherwise called water contamination (Pandey and Shukla, 2005).

The immediate impact of waste effluents on water bodies is to reduce the physical nature of water. This is followed by a biological impact on the aquatic system and its living organisms. Frequently, the aquatic system usually absorbs the waste products and materials discharged into it without critically affecting some water quality characteristics due to the process of self-purification of aquatic environments (Ifabiyi, 2008).

The discharge of waste products into water bodies has decreased water accessibility required to support typical aquatic life activities (Odigie and Fajemirokun, 2005). The pollution of aquatic systems such as ground and surface water bodies is serious issues emerging from contamination because of wastewater discharge from industries. These industries release undesirable water from their activities and are improperly released into the aquatic environment or water bodies. Its qualities give fundamental data about the quality of the receiving rivers and streams they are released (Kanu et al., 2006). The release of industrial effluents has driven unavoidably, to modification in the quality and biology of accepting water bodies (Ogbeibu and Edutie, 2002).

Port Harcourt City is presently booming with industrial activities. A portion of these enterprises arranged some good ways from streams; their effluents are directed into such waterways as Woji/Okujago River. One of these industries is a soft drink industry and agricultural activities near the river's slaughter market. The wastewater effluents from these industries' activities are conveyed over a distance through channels and discharged into the river. Also, waste food products from the slaughter market activities are discharged directly into the river without treatment. These effluents, which are abundant with natural and inorganic substances, are fit for delivering unfavorable consequences for the physical, compound, and biotic segments of the earth and affect either straightforwardly or in a roundabout way on human wellbeing (Ogbeibu and Ezeunara, 2002).

Wastewater from domestic and industrial activities, especially the slaughter market, is usually disposed into the Woji/Okujago River without satisfactory treatment preceding the release. This routine with regards to direct release of industrial wastewater into getting water bodies is of significant worry as it could result in addition to other things in a generous increment in natural burden and thus in consumption of the broke down oxygen substance of the accepting water body (Flores-Laureano and Navar, 2002; McAvoy et al., 2003).

The World Health Organisation (WHO) has also outlined guidelines for health and aesthetic situations, which shows the minimum requirements for an array of physical, chemical, biological, and radiological aspects to ensure that drinking water is safe for consumption. These guidelines serve as guidance on what can be considered safe drinking water and directions to assist nations in developing their drinking water guidelines (WHO, 2006).

Wastes products from slaughterhouses comprise blood fat, bones, oil, hair, quills, tissue, compost, coarseness and undigested feed, and wastewater used to clean the slaughtered animals (Bull et al., 1982). Based on a World Bank report, the aggregate sum of waste created from slaughtered animals per creature (cow) is around 35% of its weight. It was estimated that the average weight of a developed cow is given as 400kg (thin), 550kg (moderate), or 750kg (very fat). Scahill, 2003, also educated that if a dairy animal weighs 400kg, the body would be about 200kg after butcher (half). After going through the butcher, it loses around 33% in fat and bone. A 400kg live-weight creature should give 140kg (35%) of eatable meat along these lines. Gannon et al. (2004) additionally revealed from studies conducted by them that each dairy animal butchered produces 13.6kg of blood (with ox-like blood thickness running between 0.01g/cc – 0.15g/cc). Also, the measure of water required for the rendering (preparing) of butchered creatures ranges from 1.5 - 10m3/ton of item for pigs, 2.5 - 40 m3/ton of item for dairy cattle, and 6 - 30 m3/ton of item for poultry. Scahill (2003) accepts 2.5m3 of water is utilized to process each dairy animal butchered.

Research studies have shown that waste effluents from wastewater and sewage release prompting water contamination have turned into an issue of impressive open and logical worries in the light of proof of their extraordinary poisonous quality to human wellbeing and biological systems. Uncontrolled residential wastewater release into streams and waterways with no type of treatment has brought about eutrophication of the water bodies as proof by significant algal blossom; break up oxygen exhaustion in the subsurface water prompts huge fish to execute and other oxygen requiring living beings (Qadir et al., 2008; Pandey, 2006). The release of waste materials in excess and other harmful substances may harm aquatic bodies. Sewage released into the earth with improved centralization of supplements, dregs, and poisonous substances may negatively affect the quality and life types of the accepting water body when released untreated or incompletely treated (Schulz and Howe, 2000).

As indicated by Perry et al. (2007), nitrogen or phosphorus or both may make amphibian organic profitability increment, bringing about low broke down oxygen and eutrophication of lakes, streams, estuaries, and marine waters. Mott and Associates (2001) focused on that numerous genuine human sicknesses are brought about by waterborne pathogens. In created nations, the spread of waterborne ailments has been to a great extent captured through the presentation of water and sewage offices and cleanliness. Be that as it may, in many creating nations, such ailments are significant for death, particularly youthful ones.

The proportion of the corrosive equalization of a Solution (pH) changes can trip the biological parity of the oceanic framework, and exorbitant acridity can bring about hydrogen sulfide. The pH of water influences the dissolvability of numerous poisonous and nutritive synthetic concoctions; subsequently, the accessibility of the substances to oceanic living beings is influenced. Mosley et al. (2004) saw that water with PH > 8.5 shows that the water is hard. Most metals become more water solvent and progressively harmful to increment in acridity. Danger cyanides and sulfides additionally increment with an abatement in pH. The substance of dangerous types of alkali to the nontoxic structure additionally relies upon PH elements. Looking at the spot of electrical conductivity in deciding the nature of water, Tariq et al. (2006) opined that it is a component of absolute broken up solids known as particle focus, which decide the nature of water.

Mosley et al. (2004) were of the sentiment that electrical conductivity is a proportion of how much all-out salt (Inorganic particles, for example, sodium, chloride, magnesium, calcium) is available in the water. As indicated by them, the more particles, the higher the conductivity. Conductivity itself isn't of human amphibian wellbeing concern, but it can fill in as a pointer of other water quality issues since it is effectively estimated. If a stream's conductivity abruptly builds, it demonstrates a wellspring of broken-down particles in the region. In this way, conductivity estimations can be utilized as a snappy method to find potential water quality issues. Every normal water containing some broke down solids because of the disintegration and enduring of rocks and soils. A few, not the whole broken up solids, notwithstanding, act conceivably unfortunate. Nadia (2006) noticed that release of wastewater with a high complete disintegrated solids level would have an unfavorable effect on oceanic life, rendering the accepting water unfit for drinking and residential purposes. It likewise lessens harvest yield whenever utilized for the water systems, just as fuel consumption in water systems.

Nyanda (2000) believed that plant supplements, especially nitrogen and phosphorus, are significant determinants of the natural efficiency of amphibian biological systems. Modern discharges, creature waste, and sewage contain large amounts of nitrogen and phosphor utilizing – other real wellsprings of compost keep running off from urban and agricultural catchments. While the long haul social eutrophication quickens, the normal successional advancement of sea-going environments towards an earthly framework temporarily, issues emerge because of cyclic events of algal blossoms and rot. In a warm climate, supplements animate the fast development of green growth and coasting sea-going weeds. The water regularly winds up murky and has a terrible taste and scent. Aside from adding to supplement the substance of water, the option of certain types of nitrogen and phosphorus will build BOD and COD (Mahdieh and Amirohossein, 2009).

Agedengbe et al. (2003) noticed that a significant contamination list of modern wastewaters is the oxygen capacity estimated regarding synthetic oxygen request and organic oxygen request. The supplement status of wastewater is estimated as far as nitrogen and phosphorous. In any case, Ezenobi et al. (2004) included that PH, temperature, and all-out suspended solids are other significant-quality parameters. The profluent complete hardness convergences of a substance natural treatment plant were discovered more noteworthy than the influents (Ogunfokowokan, 1998).

In an investigation to evaluate the occasional variety in bacterial substantial metal biosorption in an accepting waterway as influenced by industrial effluents, Kanu et al. (2006) watched a general regular variety of overwhelming metals, for example, lead and zinc in the windy season when contrasted with different metals for the dry season. The centralizations of substantial metals were additionally commonly low in some examples, and no comparable patterns were seen in the control tests. Except for iron and zinc, the groupings of the overwhelming metals were generally low. Besides, profluent from the cleanser assembling plant contained critical convergences of oil and oil, adding up to 563mg.

This study evaluates the depletion of dissolved Oxygen in Woji/Okujagu River in Port Harcourt Local Government Area of Rivers State. This aim was achieved through some specific objectives; identifying sources of pollution along with Woji/Okujagu River determination of the geometric and hydraulic parameters of the river, testing the physical and chemical parameters of the river along the pollution source comparing the parameters obtained with drinking water standards and determine the water pollution index of the receiving river, determining the depletion of Dissolved Oxygen (DO) in the receiving river using Thomas slope, O′Connor reaeration, and Streeter-Phelps models. S

II. MATERIALS AND METHODOLOGY

A. Sampling

To achieve the objectives of this study, the following were carried out:

- A site survey of a pre-selected river segment was done to observe the uses to which people put the river resource and if there is any abuse.
- SA point source/pollution zone caused by the abattoir effluent discharge into the river was identified.
- The water samples representing the various points affected by the pollution were obtained from six (6) selected stations (stations A, B, C, D, E, and F) along the river located at 200m intervals from the discharge point.
- The river segment's geometric and hydraulic parameters such as depth, cross-sectional area, temperature, and velocity were obtained at the points where water samples were taken.

After that, the water samples were transported without delay to the Chemistry Laboratory, Faculty of Science, Rivers State University Nkpolu, Port Harcourt, for sample analysis.

a) Sampling Design

Sampling was done using random grab sampling. The water samples were collected during the dry season (February 2017) and wet season (August 2017) from six (6) selected stations (stations A, B, C, D, E, and F) along the river at 200m interval upstream and downstream from the point of effluent discharge. Sampling was carried out three times each month from each selected site to make a date reliable. Samples of water were obtained from the mid-width of the Woji River, utilizing clean one-liter plastic containers. The plastic containers were cleaned, soaked in 10% nitric acid, and rinsed thrice with distilled water before use. Three one-liter samples were obtained at every one of the six sampling sites. A detailed description of the sampling sites is given in Table 1.

Table 1: Description of Sampling Stations

Designation	Sampling points
Station A	200m from the point of waste discharge upstream.
Station B	Point of effluent discharge.
Station C	200m from the point of waste discharge downstream.
Station D	400m from the point of waste discharge downstream
Station E	600m from the point of waste discharge downstream
Station F	800m from the point of waste discharge downstream

b)Quality Control and Assurance

Quality assurance was considered during field sampling operations by taking the utmost care to obtain representative samples. Certain parameters, for example, pH, temperature, Dissolved Oxygen, and conductivity, are best decided in-situ (Canadian Government, 1983). This is because their qualities can change inside a generally brief time on separation from its parent body without much of a stretch. Be that as it may, it isn't constantly practicable to take gear to the site. Satisfactory calculated plans must have along these lines been made before field inspecting activity to transport the examples to the research center with the least loss of time. A portion of the examples may likewise require compound reagents to save them. Simultaneously, a few parameters of concern necessitate that exceptional holders (be it obscure glass or plastic by and large) be given. The jugs themselves must be new as well as appropriately cleaned before use. This is because specific microorganisms, components, or mixes could, in any case, stay inside a holder even after being altogether washed with refined water.

Fig 1: Collection of Water Samples from Woji/Okujago River

B.Geometric and Hydraulic Parameters

The river's geometric and hydraulic parameters at each pre-selected distance location, namely, river width, depth, and velocity, were obtained at the very points where the samples were taken. In the absence of a current meter used to obtain velocity, a distance of 2m was marked along the riverbed, and a small cork was dropped at the starting point. At the very instant, the leaf was dropped, a stopwatch was activated. The time it took the cork to travel the 2m-distance was then recorded in seconds. Also, the river morphology was estimated by taking three measurements of the depth at three equally spaced intervals (A, B, C) and the width, D using a line (rope) tied to a 2kg pendulum bulb and fastened to a measuring tape.

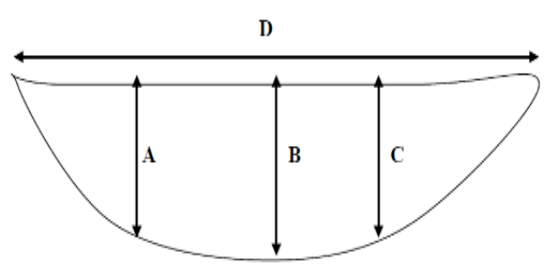

Fig 2: Measurement of the geometric parameters of the river

C. Evaluation of Water Quality Parameters

The following physical and chemical parameters were analyzed from the samples obtained from the sites: Temperature, Turbidity, Hydrogen ion concentration (pH), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), nitrates and phosphates. The tests were carried out by utilizing standard water and wastewater quality determination methods (APHA, 1998).

a)Temperature

The temperature was determined in situ by dipping the thermometer of the 110^0C calibration range into the water, and the reading is taken after 5 minutes interval (APHA, 1998).

b) Turbidity

This was measured by using the turbidity meter. The sample water was placed in the small tube of the turbidity meter. The turbidity meter was switched on, and then the reading was taken (APHA, 1998).

c) Total Solids (TS)

This was measured using a gravimetric method involving filtration and evaporation. Ten (10) milliliters of the samples were added into a dry evaporating dish that has been weighted. The dish is placed in an oven at a temperature of 103 to 105°C for two and a half hours to dry its contents. The dish was allowed to cool at room temperature and was re-weighed after transferring it to a desiccator.

The total solid was determined by observing the difference in its weight before and after evaporation (APHA, 1998).

$$\text{TS (mg/l)} = \frac{(W2-W1)}{V} \qquad 2.1$$

Where W_1 = initial weight of evaporating dish (mg), W_2 = Final weight of the dish (dish + residue) (mg) ,V = Volume of sample filtered (L)

d) Total Dissolved Solids (TDS)

The Gravimetric Method was also used to determine the TDS. This was done by filtering a portion of the sample water and putting 10ml of the filtrate into a pre-weighed evaporating dish. A similar procedure for the determination of TS was used to determine the water's TDS content as follows: (APHA, 1998).

$$\text{TS (mg/l)} = \frac{(W2-W1)}{V} \qquad 2.2$$

Where W_1 = initial weight of evaporating dish (mg), W_2 = Final weight of the dish (dish + residue) mg, V = Volume of sample filtered (L).

e)Total Suspended Solids (TSS)

This is calculated as follows:

$$\text{TSS} = \text{TS} - \text{TDS} \qquad 2.3$$

f) Electrical Conductivity (EC)

The conductivity meter was used to determine electrical conductivity. The test probe was placed into the container with the water samples until stable readings were obtained and recorded (APHA, 1998).

g) The pH

The pH was done in-situ at the site of test accumulation utilizing an electronic compact pH meter. The pH meter was aligned with phosphate buffer of known pH. It utilizes terminals that are free from the impedance. A consistent temperature, a pH change delivers a comparing change in the electrical property of the arrangement. The anode perused this change, and the exactness was the best in the center pH ranges (APHA, 1998).

h) Dissolved Oxygen (DO)

This was done using Winkler's method (APHA, 1998). The samples were placed in the DO bottles ensuring that no air was trapped. A fifth DO bottle was filled with distilled water and acted as a control for the experiment. The stopper was removed from each bottle, and the 2ml of manganous sulfate solution and alkali azide iodide solution were added in quick succession, and the stopper was carefully replaced. The contents were mixed several times, and the residue was allowed to settle halfway. They were then mixed again, and the residue was allowed to settle halfway for the second time.

2ml of concentrated sulphuric acid was added to each bottle, the stopper was replaced, and the contents mixed again until all the precipitate dissolved.

203ml was measured from the bottle and transferred to an Erlenmeyer flask and titrated against standard sodium thiosulphate solution till the color changed to pale yellow. 1ml of starch indicator solution was then added, and titration continued till the blue color disappeared. This was done for each sample and the blank. The dissolved oxygen concentration in mg/l was reported as the ml of titrant used (APHA, 1998).

i) Biochemical Oxygen Demand (BOD_5)

The strategy used to decide BOD_5 was carried out by filling the samples to flooding in an impermeable jug of the predefined size and hatching it at the predetermined temperature for 5days. The Dissolved Oxygen (DO) was estimated first and after hatching, and the BOD were resolved from the contrast among beginning and last estimations of (DO). Since the underlying (DO) was resolved not long after the dilution was included, all DO after this estimation was incorporated into the BOD estimation. One milliliter (ml) of $MgSO_4$, $CaCl_2$, phosphate buffer, $FeCl_3$ was added to 1L of water. The arrangement was then shaken altogether to soak the DO. This arrangement was utilized to dilute the tests. One hundred milliliters (100ml) of the samples were estimated into various one Liter flagons and were made up to (1L) mark with the weakening water recently arranged. The dilution sample solution was then poured into BOD bottles and subsequently incubated at 20°C in the dark for 5 days (APHA, 1998).

Determination of initial DO: 300ml BOD containers was loaded up with the diluted samples recently arranged, and the underlying DO was resolved to utilize the Winkler's strategy (APHA, 1998).

Determination of Final DO: After incubation for 5days, the final dissolved Oxygen (DO) was determined using the same procedure above

$$\text{BOD (mg/L)} = \frac{(DO2-DO1)}{V} \quad 2.4$$

Where DO_1 = initial dissolved oxygen (immediately after preparation), DO_2 = final dissolved oxygen (after 5days of incubation), V = volumetric fraction of sample used (APHA, 1998).

j) Nitrates (NO^{3-}) (Cadmium Reduction Method

Nitrite (NO^{2-}) is decreased to nitrate (NO^{3-}) within sight of Cadmium (Cd). This technique utilizes economically accessible Cd granules covered with 2% copper sulfate ($CuSO_4$) pressed in a glass section. The Nitrate (NO^{3-}) delivered is controlled by diazotizing it with shading reagent containing sulfanilamide combined with N-(1-naphthyl)- ethylenediamine dihydrochloride (NEDD) to form profoundly colourednaphthyl)- ethylenediamine dihydrochloride (NEDD) to form profoundly colored die. The shading created is estimated at colorimetrically at 410nm. A redress was made for any NO3–present in the example by examining the example without the decrease step. A standard diagram was plotted to acquire the factor (APHA, 1998).

D. Statistical Analysis and DO Determination

Mean, and the standard deviation was used to present the laboratory analysis results obtained from the stream samples' physicochemical parameters. The changes in the receiving stream's physicochemical parameters were subjected to data analysis using Microsoft Excel 2010. Further analysis was taken into account to determine water pollution index (WPI) and depletion of dissolved oxygen in the river by applying the extended version of Thomas slope and O′Connor reaeration and Streeter-Phelps models, respectively, to determine the decomposition characteristics of the receiving river.

III. RESULT AND DISCUSSION

A. Sources of Pollution along Woji/Okujagu River

The major sources of pollution identified along the river include the following:

- Dumping of wastes such as animal wastes and blood from slaughtered animals are disposed into shallow gutters around the slaughtering ground, which drain into the river.
- Waste parts of the slaughtered animals such as flesh, bones, fat, grease, undigested feed, hair, feathers, manure, grit, and abattoir wastewater were also released into the river.
- Activities from the slaughter market also produce diverse wastes that are also disposed of into the river.
- Agricultural wastes originate in the form of runoff from fields and animal farms.
- Industrial wastes from nearby industries such as Baker Hughes, Halliburton, Schlumberger, Coca Cola Bottling Company, WW white Rivoc, etc.

B. Geometric and Hydraulic Parameters of Woji/Okujagu River

In the analysis of the DO sag curve for evaluating the water quality problems, Woji/Okujagu River, the following important steps were taken:

- Presentation of the hydraulic data and picture of the current condition and taking not of every situation given in the problems;
- Determining the DO and BOD after the influent mix with the river;
- Determining travel time and rate constants necessary for the river;
- Determining the oxygen deficit and the dissolved oxygen at the given sampling stations by using appropriate model equations;
- Determining the critical time and the critical deficit.

C. Physical and Chemical Parameters of the River

Tables 3 - 4 presented below show the physical and chemical tests carried out on the water samples from the river. The results were expressed in mean ± standard deviation for dry season (February 2017) and wet season (August 2017) while Tables 5 - 6 compares the range and mean values of physicochemical parameters of dry and wet seasons with WHO and NESREA standards. The physicochemical parameters examined include Temperature, Hydrogen ion concentration (pH), Total Suspended Solids (TSS), Electrical Conductivity (EC), Nitrates, Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO).

D. Pollution Index of Woji/Okujagu River

To ascertain the extent of pollution as it affects the aquatic environment, the pollution index (PI) of the water samples was estimated as follows:

$$PI = 1/n[M_1/T_1 + M_2/T_2 + M_3/T_3 + \ldots M_n/T_n] \quad 3.1$$

Where,

$M_1, M_2 \ldots M_n$ are the mean concentration of the parameters, $T_1, T_2 \ldots T_n$are the acceptable levels for each parameter, and ,n, is the sampled number of parameters.

Any value of PI value greater than 1.0 implies that the parameter's average concentration is above the safe water quality limit. PI is classified as low contamination (PI≤1), moderate contamination (1<PI≤3), or high contamination (PI>3). Mean values of dry and wet seasons for each sampling station were used to compute the PI of the water samples, as shown in table 4.6. The results of the pollution index indicate that the pollution index is greater than 1.0 in all sites. Therefore the river is classified as moderate contamination (1<PI≤3) or class 4.

Table 2: The geometric and hydraulic data obtained from Woji/Okujagu River

Sampling Stations	Distance x (m)	Depth, d (m)	Width, w (m)	Area $A = w \times d$ (m²)	Velocity, V (m/s)	Flow Rate $Q = AV$ (m³⁄s)
A	0	5.25	14.25	74.81	0.014	1.047
B	200	6.32	10.45	66.04	0.015	0.991
C	400	6.85	7.84	53.70	0.018	0.967
D	600	7.32	12.30	90.04	0.016	1.441
E	800	8.20	21.54	176.63	0.019	3.356
F	1000	8.54	20.40	174.22	0.017	2.962
Average		7.08	14.46	105.91	0.017	1.794

Table 3: Physical and chemical parameters at various sampling stations at Woji/Okujagu River during the dry season (February 2017)

Water Parameters	Station A	Station B	Station C	Station D	Station E	Station F
Temp. (^{0}C)	27.8 ± 0.6	29.5 ± 1.6	28.7 ± 0.8	27.6 ± 0.2	27.5 ± 0.5	26.5 ± 0.2
TSS (mg/L)	145.6±21.2	247.9±21.2	183.8±81.4	176.9±48.0	158.0±33.6	162.0±25.1
EC (µS/cm)	435.5± 3.2	905.3± 9.4	741.1± 5.1	588.0± 3.2	422.7± 3.7	430.5± 2.8
pH	6.1 ± 0.2	6.0 ± 0.2	6.0 ± 0.2	6.1 ± 0.1	6.2 ± 0.1	6.4 ± 0.5
Nitrates (mg/L)	17.6 ± 0.2	97.3 ± 1.2	85.9 ± 0.3	65.8 ± 0.6	32.6 ± 0.8	25.5 ± 0.8
BOD_5 (mg/L)	62.4 ± 1.8	75.2 ± 3.8	65.8 ± 3.2	52.2 ± 2.5	42.5 ± 1.2	44.2 ± 2.2
DO (mg/L)	4.5 ± 0.2	2.2 ± 0.1	3.6 ± 0.1	4.1 ± 0.1	5.8 ± 0.2	6.2 ± 0.5

Table 4: Physical and chemical parameters at various sampling stations at Woji/Okujagu River during the wet season (August 2017)

Water Parameters	Station A	Station B	Station C	Station D	Station E	Station F
Temp. (^{0}C)	25.6 ± 0.7	27.1 ± 1.2	26.5 ± 0.5	25.8 ± 0.6	25.4 ± 0.2	25.0 ± 0.4
TSS (mg/L)	285.1±35.4	484.4±47.6	418.2±68.2	334.5±72.8	296.6±24.1	250.2±32.1
EC (µS/cm)	541.2± 4.2	982.2± 9.5	852.5± 3.8	618.0± 5.1	565.4± 4.3	522.5± 3.5
pH	7.3 ± 0.4	6.7 ± 0.1	6.9 ± 0.5	7.1 ± 0.5	7.2 ± 0.2	7.5 ± 0.6
Nitrates (mg/L)	12.5 ± 0.3	58.5 ± 1.1	42.2 ± 0.5	36.8 ± 0.6	21.4 ± 0.4	18.5 ± 0.8
BOD_5 (mg/L)	38.2 ± 0.8	45.6 ± 2.1	36.5 ± 2.5	30.5 ± 1.6	22.5 ± 0.2	21.2 ± 1.4
DO (mg/L)	6.2 ± 0.5	3.2 ± 0.2	4.5 ± 0.1	5.6 ± 0.2	6.5 ± 0.4	6.8 ± 0.8

Table 5: Comparison of the range and mean values of physical and chemical parameters of dry and wet seasons from all sampling stations with WHO and NESREA standards

Water Parameters	Dry Season		Wet Season		WHO Limits	NESREA Limits
	Range	Mean	Range	Mean		
Temp. (^{0}C)	26.5 - 29.5	27.93	25.0 - 27.1	25.90	30	40
TSS (mg/L)	145.6-247.9	179.03	250.2-484.4	344.83	30	30
EC (µS/cm)	422.7-905.3	587.18	522.5-982.2	680.30	250	1000
pH	6.0 - 6.4	6.13	6.7 - 7.5	7.12	6.5 - 8.5	6 - 9
Nitrates (mg/L)	17.6 - 97.3	54.12	12.5 - 58.5	31.65	50	50
BOD_5 (mg/L)	42.5 - 75.2	97.70	21.2 - 45.6	37.23	10	30
DO (mg/L)	2.2 – 6.2	4.30	3.2 - 6.8	5.30	10	4 - 6

Table 6: Comparison of the ranges and mean values of physical and chemical parameters for both dry and wet seasons from all sampling stations with WHO and NESREA standards

Water Parameters	Range (Dry and wet)	Mean Values (Dry and wet)	WHO Limits	NESREA Limits
Temp. (^{0}C)	25.0 – 29.5	26.92	30	40
TSS (mg/L)	145.6 – 484.4	261.93	30	30
EC (µS/cm)	422.7 – 982.2	633.74	250	1000
pH	6.0 – 7.5	6.63	6.5 - 8.5	6 - 9
Nitrates (mg/L)	12.5 – 97.3	42.88	50	50
BOD_5 (mg/L)	21.2 – 75.2	67.47	10	30
DO (mg/L)	2.2 – 6.8	4.80	10	4 – 6

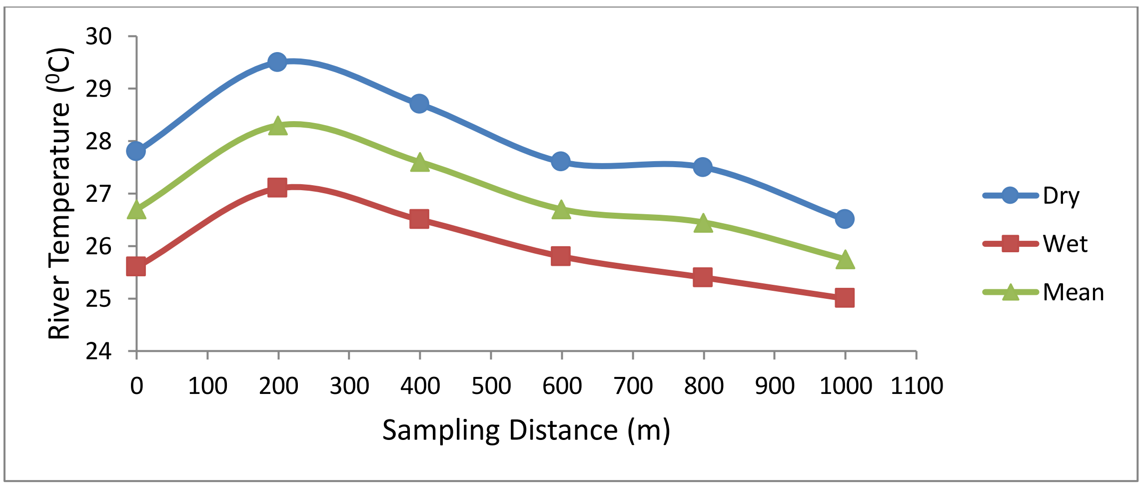

Fig 3: Variation of River Temperature with sampling distance (m)

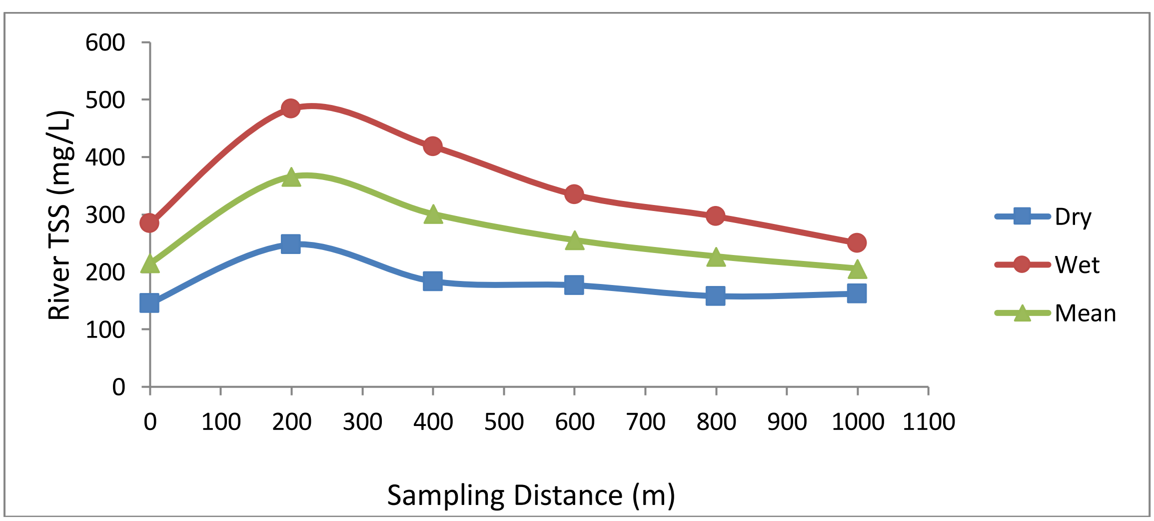

Fig. 4: Variation of River TSS with sampling distance (m)

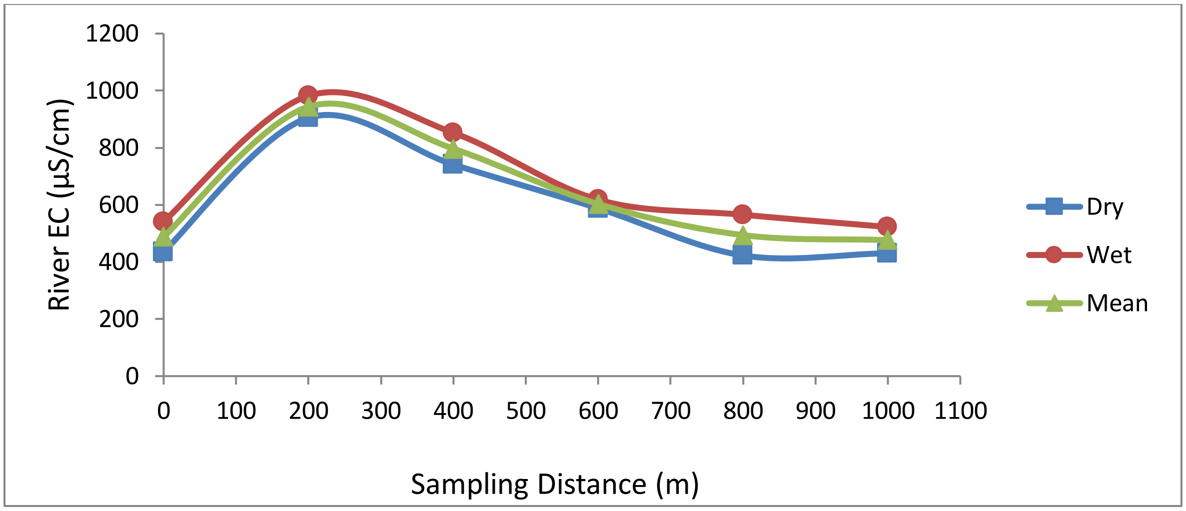

Fig. 5: Variation of River EC with sampling distance (m)

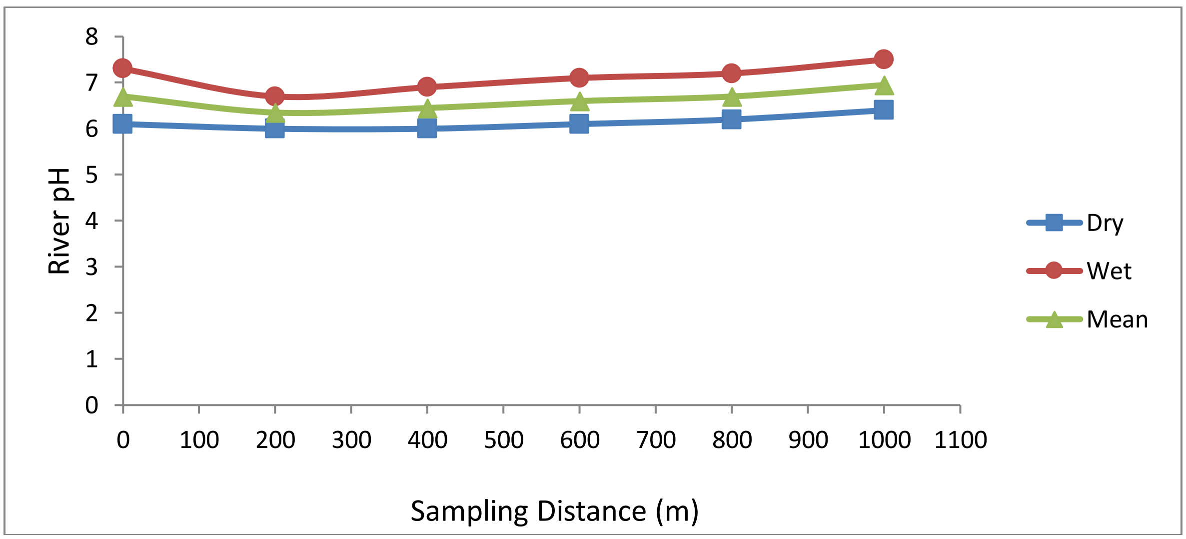

Fig. 6: Variation of River pH with sampling distance (m)

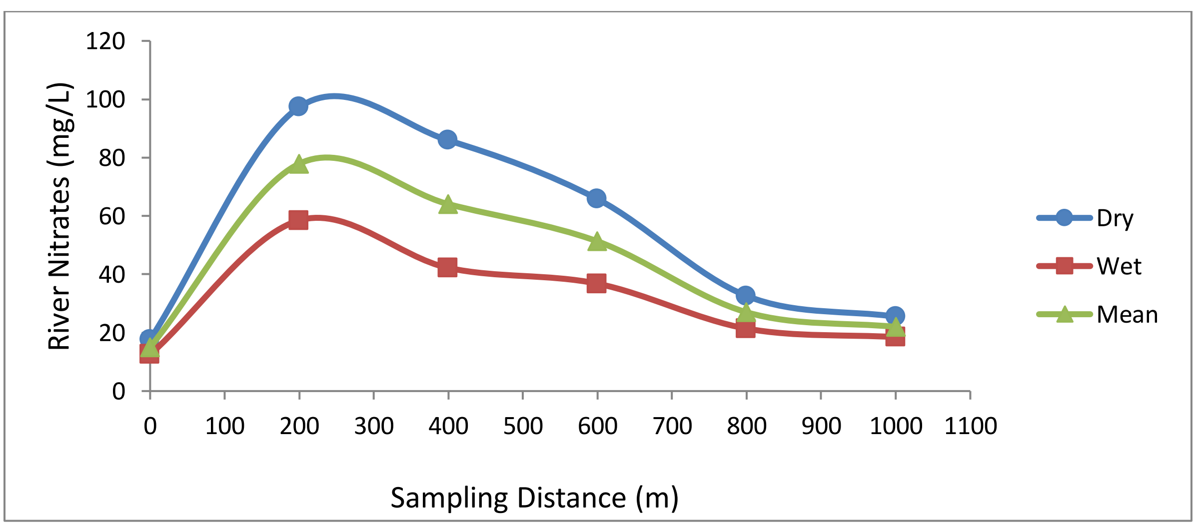

Fig. 7: Variation of River Nitrates with sampling distance (m)

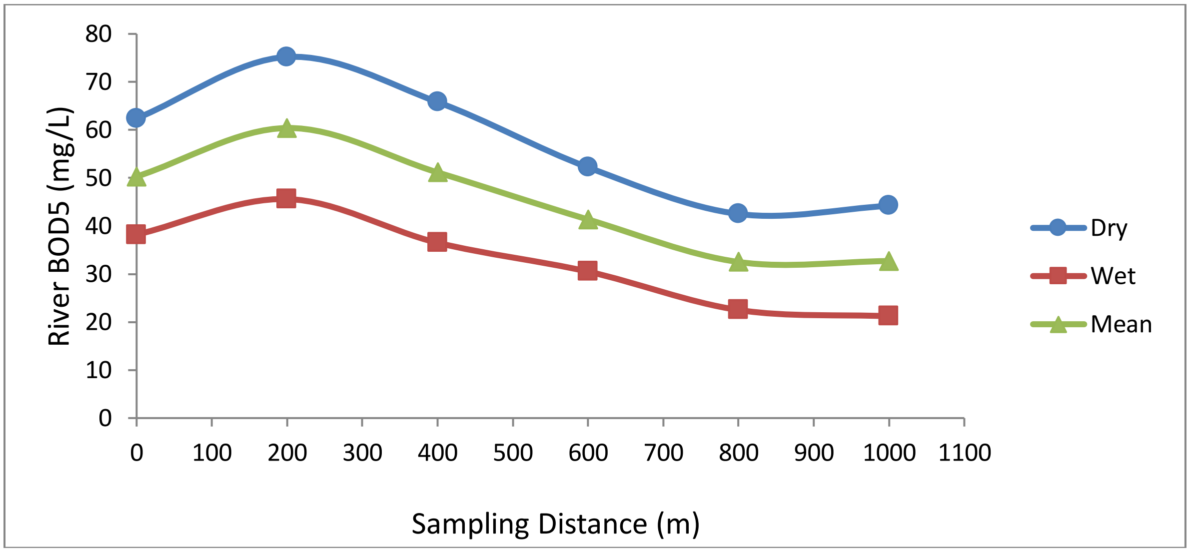

Fig. 8: Variation of River BOD_5 with sampling distance (m)

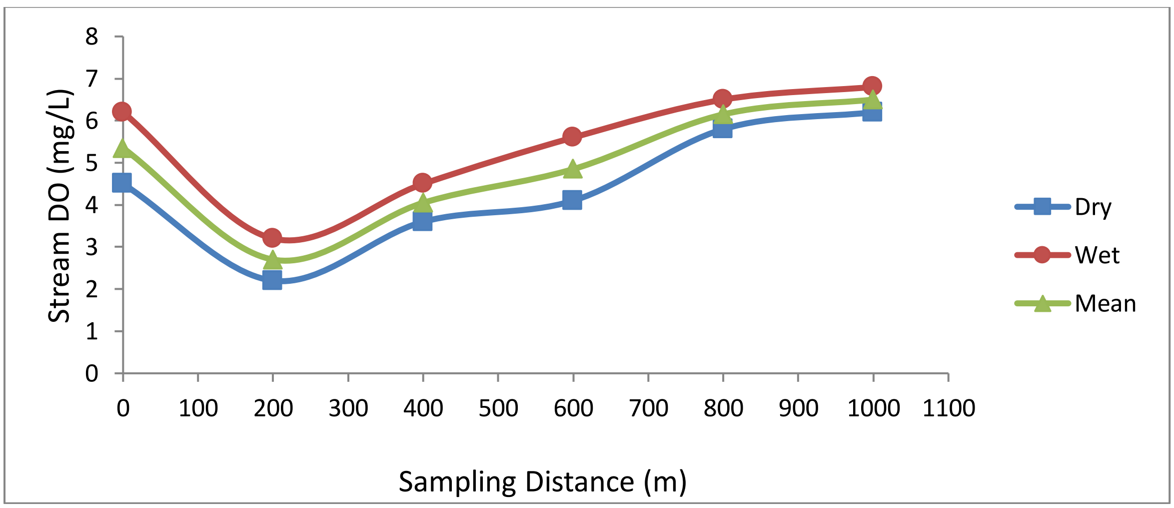

Fig. 9: Variation of River DO with sampling distance (m)

Table 7: Pollution Indices (PI) of the water samples from each sampling station

Water Parameters	Station A	Station B	Station C	Station D	Station E	Station F	NESREA Standard
Temp. (^{0}C)	26.7	28.3	27.6	26.7	26.45	25.75	40
TSS (mg/L)	215.35	366.15	301	255.7	227.3	206.1	30
EC (µS/cm)	488.35	943.75	796.8	603	494.05	476.5	1000
pH	6.70	6.35	6.45	6.60	6.70	6.95	9
Nitrates (mg/L)	15.05	77.90	64.05	51.30	27.0	22.0	50
BOD_5 (mg/L)	50.3	60.4	51.15	41.35	32.5	32.7	30
DO (mg/L)	5.35	1.90	4.05	4.85	6.15	6.50	6
PI	1.950	3.8927	3.0797	2.5077	2.1101	2.050	

Table 8: The pollution index (PI) of the water samples of physical and chemical parameters from all sampling stations

Water Parameters	Mean Values (M_n)	Tolerable Levels (T_n)	Sub-Index (M_n/T_n)
Temp. (^{0}C)	27.15	27	1.0056
TSS (mg/L)	273.1	30	9.1033
EC (µS/cm)	665.19	200	3.3259
pH	6.56	9	0.7289
Nitrates (mg/L)	47.06	30	1.5687
BOD5 (mg/L)	47.14	30	1.5713
DO (mg/L)	4.46	6	0.7433
Pollution Index (PI)			2.5781

E. DO Sag Curve of Woji/Okujagu River

Figure 4.8 is the DO sag curve used for Woji/Okujagu River, showing the variation of DO concentration against distance, x (m) from the sampling stations in the direction of flow.

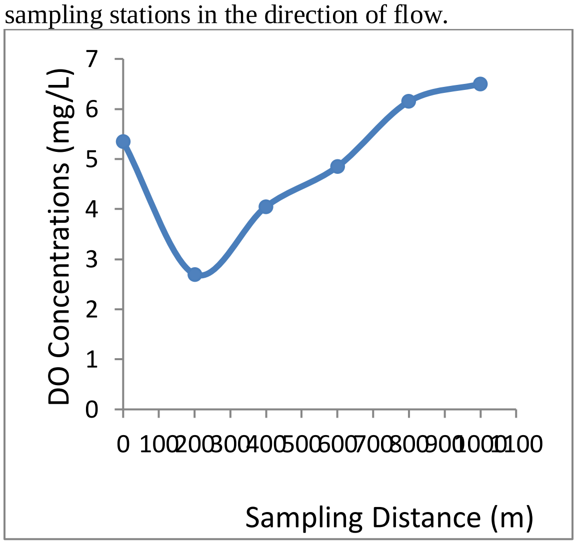

Fig. 10: Variation of DO concentration with sampling distance x (m)

From the DO sag curve above, the waste effluents enter the river at the point of discharge. At this point, distance (x) = 0 and time (t) = 0, the disintegration process takes oxygen faster than the reaeration process replaces the oxygen. As a result of this, the DO drops drastically to its minimum at some point near the discharge area downstream, and this process occurs at the critical time t_c. As a result of self-purification at this point, reaeration slowly becomes more than deoxygenation, and the stream recovers its natural forms steadily.

The Critical time t_c was evaluated as shown below.

$$t_c = \frac{Distance\ along\ the\ stream,\ x}{Average\ velocity\ of\ stream,\ U} \quad 3.2$$

where x = 200m and U = 0.017 m/s

t_c = 200/0.017 = 11765 s
= 11765/(60 × 60 × 24) days
= 0.1362 days

a) Thomas Slope's De-oxygenation Constant K_d and Ultimate (BOD) L_o,

The Thomas Slope method can be used to determine the deoxygenation constant K_d and ultimate (BOD) L_o, by plotting $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ As a function of t. The slope b and the intercept a of the line of best fit can be used to estimate the values of K_d and L_o using equations (3.3) and (3.4) as follows:

$$K_d = (2.61)\frac{b}{a} \quad 3.3$$

$$L_o = \frac{1}{2.3K_d a^3} \quad 3.4$$

where y = exerted BOD, K_d = de-oxygenation rate constant, L_o = ultimate BOD, a, and b are constants.

Table 9: Computation of $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ from BOD$_5$ mean values obtained from experimental analysis

Time (days)	BOD (y) (mg/l)	$(t/y)^{1/3}$
1	50.3	0.2709
2	60.4	0.3211
3	51.15	0.3885
4	41.35	0.4590
5	32.5	0.5358

The values from Table 9 was used to determine the variation of $(t/y)^{1/3}$ with time to obtain the values of K_d and L_o in Fig. 11 shown below.

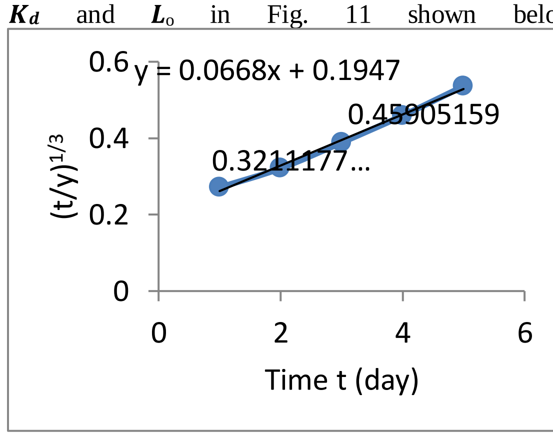

Fig. 11: Variation of the function of exerted BOD $(t/y)^{1/3}$ with time (t)

The linear equation of the graph is $y = 0.0668x + 0.1947$

The intercept is obtained when x = 0, Intercept $\boldsymbol{a} = 0.1947$, Slope $\boldsymbol{b} = \frac{y2-y1}{x2-x1}$

Slope $\boldsymbol{b} = \frac{0.4590 - 0.3211}{4-2}$

Slope $\boldsymbol{b} = 0.683$

From Equation (3.3), $K_d = (2.61)\frac{b}{a}$

$$K_d = (2.61)\frac{0.1947}{0.683}$$

$$K_d = 0.744$$

From Equation (3.4), the ultimate BOD is $L_o = \frac{1}{2.3K_d a^3}$

$$L_o = \frac{1}{2.3 \times 0.744 \times 0.1947^3}$$

$$L_o = 79.2mg/l$$

b) Re-aeration Constant** K_r **using O' Connor Model

The O' Connor model was used to determine the reaeration constant, K_r, as shown in Equation (3.5).

$$K_r = \frac{3.9V^{0.5}}{H^{\frac{3}{2}}} \qquad 3.5$$

Where V = mean stream velocity = 0.0164 m/s (Table 2)

H = average depth of river = 6.788m (Table 2)

$$K_r = \frac{3.9 \times (0.0164)^{0.5}}{(6.788)^{\frac{3}{2}}} = \frac{0.4994}{17.685}$$

$$K_r = 0.0282$$

c) Dissolved oxygen using Streeter - Phelps model

The DO of Woji/Okujagu River was determined using the Streeter-Phelps model from Equation (3.6) as follows:

$$D_t = \frac{K_d L_o}{K_r - K_d}\left(e^{-K_d t} - e^{-K_r t}\right) + D_o\left(e^{-K_r t}\right) \qquad 3.6$$

Where D_t = oxygen deficit in the river at time t, L_o = initial ultimate BOD at mix, D_o = initial oxygen deficit at the mix, K_d= de-oxygenation rate constant, K_r = re-aeration rate constant, t_c = critical time.

In the process of evaluating the DO deficit of Woji/Okujagu River, the critical time of the deficit was first determined from Equation (3.2) as shown in table 10:

Table 10: The Critical time for DO deficit occurrence

Stations	x (m)	U (m/s)	t_c (days)
A	0	0.017	0
B	200	0.017	0.1362
C	400	0.017	0.2723
D	600	0.017	0.4085
E	800	0.017	0.5447
F	1000	0.017	0.6808

From the estimation of the critical time in Table 10, the DO at the various sampling points can also be evaluated from the Streeter-Phelps equation using a developed Excel template as presented in Table 11.

Table 11: Dissolved Oxygen (DO) deficit estimation

Stations	t (days)	K_d	K_r	L_o	K_r-K_d	$\frac{K_d L_o}{K_r - K_d}$	$e^{-K_d t}$	$e^{-K_r t}$	$(e^{-K_d t}) - (e^{-K_r t})$	D_o	$D_o(e^{-K_r t})$	D_t
A	0	0.744	0.0282	79.2	-0.716	-82.30	2.718	2.718	0	5.35	5.35	5.350
B	0.1362	0.744	0.0282	79.2	-0.716	-82.30	0.924	0.990	-0.066	5.35	2.375	3.45
C	0.2723	0.744	0.0282	79.2	-0.716	-82.30	0.883	0.984	-0.101	5.35	2.361	4.13
D	0.4085	0.744	0.0282	79.2	-0.716	-82.30	0.849	0.978	-0.130	5.35	2.348	4.73
E	0.5447	0.744	0.0282	79.2	-0.716	-82.30	0.816	0.973	-0.158	5.35	2.336	5.28
F	0.6808	0.744	0.0282	79.2	-0.716	-82.30	0.785	0.962	-0.176	5.35	2.412	5.76

The last column of Table 11 was combined with the estimated mean values of DO from Table 7 from the appendix to plot the DO sag curve. The measured DO sag curve was compared with the curve derived from Streeter-Phelp simulated model, as shown in fig. 12. The predicted values of dissolved oxygen were also plotted against the measured value of dissolved oxygen, and the correlation (R^2) between the two values was determined in figure 12.

Table 12: Comparison between measured and simulated DO concerning the time

Stations	t (days)	D_o (Measured)	D_t (Simulated)
A	0	5.35	5.350
B	0.1362	2.7	3.45
C	0.2723	4.05	4.13
D	0.4085	4.85	4.73
E	0.5447	6.15	5.28
F	0.6808	6.50	5.76

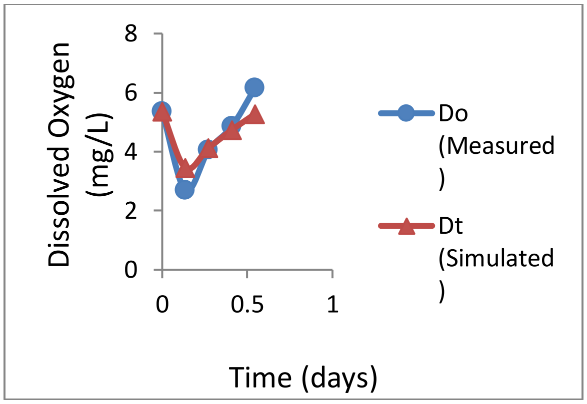

Figure 12: Variation of Simulated and Measured DO Sag Curve for Woji/Okujagu River

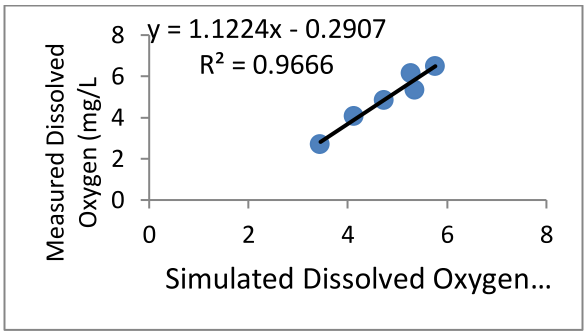

Fig. 13: Variation of the Simulated and Measured DO for Woji/Okujagu River

E. Discussion of Results

The characteristics of Woji/Okujagu River during wet and dry seasons connected with the stations sampled were compared using standard estimations of WHO (2004) and the NESREA (2007) as indicated in Table 4. The temperature ranged from 27.5 to 29.5°C, having a mean value of 28.22°C for the dry season and 25.4 to 27.1°C having a mean value of 26.08°C for the wet season. The observed difference in the two seasons was because temperature tends to be higher in the dry season, as reported by NIMET (2009). The mean temperature obtained from the Woji/Okujagu River sampling stations during the dry and wet seasons was low at the upstream at 26.7^{0}C. Still, it increased steadily from the point of discharge to midstream and downstream with temperature values of 28.3^{0}C, 27.6^{0}C, and 26.4^{0}C, respectively. The mean temperature was within permissible limits of WHO and NESREA. This observation agrees with the findings of Igbinosa et al. (2012).

TSS varied from 145.6 to 247.9mg/L with a mean value of 182.4mg/L for the dry season and varied from 285.1 to 484.4mg/L for the wet season value of 363.8mg/L. TSS's mean values were low at the upstream with a value of 215.3mg/l and higher at the point of discharge with 366.1mg/l but reduced substantially at the downstream with a value of 227.3mg/l. The deposition of solid particulates from the effluent at the point of discharge through the Creek course could increase TSS volume from the upstream to downstream (lower course). These values were above the permissible limits of WHO and NESREA. This is in agreement with the Study of Raman et al. (2009).

The EC for the dry season ranged from 422.7 to 905.3 with a mean value of 618.52/µscm, while the wet season ranged from 541.2 to 982.2 with a mean value of 711.86/µscm. The mean EC values increased from the upstream with a mean value of 488.3µScm^{-1} to 943.7µScm^{-1} at the point of discharge due to the sewage discharge. The mean value decreases to 494.0µScm^{-1} at the downstream. The reduction may be due to little amounts of dissolved solids in water due to dilution. Electrical conductivity is used to indicate the dissolved solids in water because the concentration of ionic species determines the conduction of current in an electrolyte (Hayashi, 2004). The mean EC values were above the WHO and NESREA standard values, which is in agreement with Anwar et al.'s (2011) findings.

The pH ranged from 6.0 to 6.2 for the dry season with a mean value of 6.08, while for the wet season, the pH range between 6.7 to 7.3 with a mean value of 7.04, which is within the permissible limits with standard limits of WHO and NESREA. These results were similar to the findings of Charkhabi and Sakizadeh (2006). Nitrate (NO_3) values varied from 17.6 to 97.3mg/L and 12.5 to 58.5mg/L with mean values of 59.84mg/L and 34.28mg/L for dry and wet seasons, respectively. It is important to note that the nitrate level in the stream could be a source of eutrophication for receiving water. The values were above the WHO and NESREA standard permissible limits. The mean values of nitrates varied from 17.6mg/L upstream to 97.3mg/L at the discharge point and reduced to 32.6mg/L downstream. The reduced level of nitrate in the downstream point could be due to the conversion of nitrates to nitrites along the stream's length.

Comparative perceptions were recorded for BOD which extended from 42.5 - 75.2mg/L and 22.5 - 45.65mg/L with normal estimations of 58.02mg/L and 32.66mg/L for dry and wet seasons, respectively. Mean BOD esteems above admissible breaking points for WHO and NESREA guidelines. BOD's mean values varied from 50.3mgL^{-1} upstream and increased to 60.4mgL^{-1} at the point of discharge, while downstream, it reduces to 32.5mgL^{-1}. The observed high values, especially at the point of discharge, might be because of the invasion of abattoir wastes into the river, which may bring about intense interest for oxygen for deterioration of natural toxins. However, the average measure of BOD downstream exceeds the recommended value of 28 - 30mgL^{-1}. It might partially be due to other non-point contamination sources or that the microbial burden far surpasses the self-sanitization limit of the stream. This concurs with the discoveries of Ololade and Ajayi (2009).

DO variations ranged from 2.2 - 5.8mg/L with mean value of 4.04mg/L for dry season and 3.2 - 6.5mg/L with mean value of 5.20mg/L for wet season, respectively. The mean values of DO were not within NESREA permissible limits. The decrease in DO during the dry season maybe because of the higher deluge of squanders along these lines diminishing the stream's natural existence. The mean value of DO upstream was 5.35mgL^{-1} and decreased to the lowest mean value of 2.7mgL^{-1} at the point of discharge. The low DO concentration at the point of discharge results from a high influx of organic load from the abattoirs and traders. The mean DO level, however, improves downstream to 6.15mgL^{-1}. This could be attributed to both the flow and recovery capacity of the stream.

The pollution index results from this study indicate that the river pollution index is greater than 1 in all sites due to the high level of effluent pollution from the abattoirs and traders operating around the area of discharge. However, the level of pollution was classified as moderate contamination ($1<PI\leq3$) or class 4. The high pollution index at the point of discharge is attributed to the high influx of effluents into the river due to different anthropogenic activities, which has led to the depletion of dissolved oxygen at effluence discharge in the receiving stream. This observation is consistent with the findings of Al-Obaidy et al. (2015) and Umunnakwe et al. (2011). Similarly, Rim-Rukeh, (2013) observed that the water quality index (WQI) of Oguta lake, Omuku pond, Ugheghe pond, Karabodone lake, and Abua lake are 67.46, 65.64, 65.87, 50.77, and 67.01 respectively and belong to class III and empirically described as average or medium.

The DO's determination in this study yielded L_o, K_d, and K_r values of $79.2mg/l$, 0.744, and 0.0282. The simulated DO values ranged from 2.921 to 5.856 from upstream to downstream. These findings agree with other studies done by other researchers. Omole (2006) accessed the impact of abattoir effluent discharge on the water quality of River Illo; Ota revealed that pollution from the abattoir caused a drop in dissolved oxygen level of the river from an ambient value of 4.6mg/l to 0.01mg/l at the point of discharge. The pollution also caused an increase of 447.5mg/l to 1071.5mg/l in TS and 170mg/l to 670mg/l in BOD. The dispersion modeling result shows the self-purification capacity of the River, f, to be 1.1 within 30m distance from the point of discharge and 0.8 between 30m and 100m from the point of discharge. The results from the Streeter-Phelps model's application showed that the eutrophication occurring between 30m – 80m is interfering adversely with the self-purification processes of the river. The percentage compliance of each of the eight water samples with Guideline Values (GLV) of WHO and NESREA was performed. None of the samples met the minimum requirements for BOD, COD, and TSS, which are pollution indicators.

Canale and Ownes (1995) estimated K_d in the river receiving secondary treated effluent as 0.1 day^{-1}. Lung (1998) studied primary and secondary treatment effects without nitrification and nitrification on the Upper Mississippi River's DO levels. Significant improvements were observed in the DO levels at higher levels of treatment. The river deoxygenation rate (K_d) was reduced from 0.27 day^{-1} for primary treated effluent to 0.19 day^{-1} for effluent that received secondary treatment. The K_d was further reduced to 0.057 day^{-1} for secondary treated effluent with nitrification.

IV. CONCLUSION

This thesis evaluates the depletion of dissolved oxygen in receiving streams at Woji/Okujagu River in Port Harcourt Local Government Area of Rivers State. The study revealed a significant effect on TSS, EC, Nitrates, BOD5, and DO parameters of water quality of the receiving stream due to the activities that result in the discharge of waste effluents from slaughterhouses.

This study revealed that most of the parameters assessed in the receiving stream are above limits recommended by the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA) and the World Health Organisation (WHO). It also showed that although the stream was already polluted from upstream activities, there was a significant increase in the levels of BOD_5, TSS, DO, EC and Nitrates at the effluent discharge point, thereby contributing to the pollution of the river and endangering the ecosystem and the health of the people who rely on it for livelihood. Thus, there is a need for proper Management of the sewage wastewater entering receiving streams to improve its quality and minimize danger to the environment and people.

REFERENCE

[1] K. Absar.,Water and Wastewater Properties and Characteristics., In J. H. Lehr and J. Keeley (Eds.), Domestic, Municipal and Industrial Water Supply and Waste Disposal (2005) 903-905, New Jersey: John Wiley and Sons, Inc.

[2] S. Adekunle., Impacts of Industrial Effluent on Quality of Well Water within Asa Dam Industrial Estate, Ilorin Nigeria. Nature and Science, 6(3)(2008) 1-5.

[3] A. S. Adekunle& I. T. K. Eniola.,Impact of Industrial Effluents on Quality of Segment Of Asa River within an Industrial Estate in Ilorin, Nigeria. New York Science Journal, 1(1)(2008) 17-21.

[4] J.A. Adelegan.,Environmental policy and slaughterhouse waste in Nigeria., Proceedings of the 28th WEDC Conference, November (2002) 18-22, , Calcutta, India, 3-6.

[5] K. Agedengbe, A. O. Akinwole, &A. O. Babatunde.,Effluents Characteristics of Selected Industries in Western Nigeria and Implications for re-use in Agricultural Production., Journal of Environmental Extension, 4(2003) 79-82.

[6] O. B. Akpor, & B. Muchie.,Environmental and public health implications of wastewater quality., African Journal of Biotechnology, 10(13)(2013) 2379-2387.

[7] O. B. Akpor& B. Muchie.,Environmental and public health implications of wastewater quality.,African Journal of Biotechnology, 10(13)(2013) 2379-2387.

[8] A. Y. Al-Ghamdi.,Review on Hospital Wastes and its Possible Treatments., Egypt Academy Journal of Biological Science, 3(1)(2011) 55-62.

[9] A. H. M. J., Al-Obaidy&M. Al-Khateeb.,Application of Water Pollution Index for Assessment of Tigris River Ecosystem., International Journal of Advanced Research, 3(2)(2015) 219-223.

[10] J. I. Anetor, F. A. A. Adeniyi,&S. B. Olaleye.,Molecular Epidemiology: A Better Approach for the Early Detection of Pathophysiologic Response to Environmental Toxicants and Diseases., African Journal of Biomedical Research, 6(2003) 113-118.

[11] APHA.(1998). Standard Methods of Examination of Water and Wastewater (20th ed.). Washington DC. J. P. S. Cabral (2010). Water Microbiology. Bacterial Pathogens and Water. International Journal of Environmental Research & Public Health, 7, 3657-3703.

[12] K. H. Barnes, J. L. Meyer&B. J. Freeman., Sedimentation and Georgia's Fishes: An analysis of existing information and future research: Georgia Water Resources Conference, University of Georgia, Athens, Georgia., (1998).

[13] M. H. Bichi& B. U. Anyata., Industrial Waste Pollution in the Kano River Basin. Journal of Environmental Management and Health, 10(2)(1999) 112-116.

[14] M. A. Bull, R. M. Sterritt& J. N. Lester.,The treatment of wastewaters from the meat industry: A Review., Environmental Technology Letters, 3(1982) 117-126.

[15] J. P. S. Cabral (2010). Water Microbiology. Bacterial Pathogens and Water. International Journal of Environmental Research & Public Health, 7, 3657-3703.

[16] S. I. B. Cadmus, B. O. Olugasa&G.A.T. Ogundipe., The prevalence of zoonotic importance of bovine tuberculosis in Ibadan, Nigeria. Proceedings of the 37th Annual Congress of the Nigerian Veterinary Medical Association,25-31(1999) 883-886 Kaduna,.

[17] R. P. Canale, E. M.Ownes& M. T. Auer., Validation of Water Quality Model for Seneca River, NY. Journal of Water Resources Planning and Management, 121(3)(1995) 12-15.

[18] D. Chapman (1996). Water Quality Assessments, A Guide to Use of Biota, Sediments, and Water in Environmental Monitoring (second ed.), London, F & FN Spon.,3- 10.

[19] A. H. Charkhabi& M.Sakizadeh.,Assessment of Spatial Variation of Water Quality Parameters in the Most Polluted Branch of the Anzali Wetland, Northern Iran., Polish Journal of Environmental Studies, 15(3)(2006) 395.

[20] G. Cornish,& A.Mensahh,. Water quality and Peri-urban irrigation. Report OD/TN95HR Willing ford. The UK., (1999).

[21] W. P. Cunningham, M. A. Cunningham, &B. Saigo,. Environmental Science: A Global Science. New York. McGraw-Hill., (2005).

[22] O. A. Davies, A. A. Ugwumba&D. S. Abolude(2008). ,Physico-chemical Quality of Trans-Amadi (Woji) Creek Port Harcourt,, Delta, Niger Delta, Nigeria. Journal of Fisheries International, 3(3)(2008) 92-97.

[23] F. O. Ekhaise& B. P. Omavwoya (2008). ,Influence of Hospital Wastewater Discharged from the University of Benin Teaching Hospital (UBTH), Benin City on its Receiving Environment., American-EurasianJournal of Agriculture & Environmental Science, 4(4)(2008) 484-488.

[24] F. O. Ekhaise& C. C. Anyansi.,Influence of breweries effluent discharge on the microbiological and physicochemical quality of Ikpoba River,, Nigeria. African Journal of Biotechnology, 4 (2005) 1062-1065.

[25] EPA., Dissolved Oxygen and Biochemical Oxygen Demand. In Water Monitoring and Assessment. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms52.cfm (2012).

[26] EPA., Dissolved Oxygen Depletion in Lake Erie. In Great Lakes Monitoring. Retrieved from http://www.epa.gov/glindicators/water/oxygenb.html(2013).

[27] S O. Fakayode., Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria, Ajeam-Ragee, 10(2005) 1-13.

[28] J. S. Flores-Laureano&J. Navar.,An assessment of stream water quality of the Rio San Juan,, Nuevo Leon, Mexico, 1995-1996. Journal of EnvirontalQuallity,31(2002) 1256-1265.

[29] V.P.Gannon, J. F. Hummenik, M. Rice, J. L. Cicmanec, Smith Jr. &Carr, R., Control of Zoonotic Pathogens in Animal Wastes, Waterborne Diseases: Identification, Causes, and Control. 1st Edn., WHO, IWA, London, UK., (2004) 409-425.

[30] V. I. Ibekwe, O. I. Nwaiwu&J. O. Offorbuike,. ,Bacteriological and physicochemical qualities of wastewater from a bottling company in Owerri, Nigeria., Global Journal of Environmental Science, 3(2004) 51-54.

[31] G. Ichobaoglous, F. L. Burton, & H. D. Stensel (2003). Wastewater Engineering, Treatment, and Reuse. Metcalf and Eddy Tata McGraw Hill Publishing Company Limited, New Delhi India.

[32] I. P. Ifabiyi(2008). ,Self Purification of a Freshwater Stream in Ile-Ife: Lessons for Water Management., Journal of Human Ecology, 24(2), 131-137.

[33] I. Kanu and O. K. Achi.,Industrial Effluents and Their Impact on Water Quality of Receiving Rivers in Nigeria., Journal of Applied Technology in Environmental Sanitation, 1(1)(2011) 75-86.

[34] I. Kanu, O. K. Achi, O. U. Ezeronye& E. C. Anyanwu(2006). ,Seasonal variation in bacterial heavy metal biosorption in water samples from Eziamariver near soap and brewery industries and the environmental health implications., International Journal of Environmental Science and Technology, 3 (1), 95-102.

[35] I. A. Kanu, O. K. Achi, O. U. Ezeronye&E.C. Anyanwu, E.C.,Seasonal variation in heavy metal biosorption in water samples from Eziama River near soap and brewery industries and environmental health implication., International Journal of Environmental Science and Technology, 3(1)(2006) 95-102.

[36] G. Kiely.,Environmental engineering technologies.,, McGraw-Hill, London, disappearance, and sludge rising in a settling column system. Water Resources, 28(9)(1998) 1831-1872.

[37] H.K Koech, G.M Ogendi& J. Kipkemboi.,Status of Treated Slaughter-House Effluent and its Effects on the Physico-Chemical Characteristics of Surface Water in Kabuthi Stream, Dagoretti-Kenya,, Research Journal of Environmental and Earth Sciences, 4(8)(2012) 789-796.

[38] W. S. Lung.,Trends in BOD/ DO modeling for waste load allocations,, Journal of Environmental Engineering, ASCE, 124(10)(1998) 1004 -1007.

[39] E. Mahdieh&M. Amirhossein(2009). Water quality assessment of Bertam River and its tributaries in Cameron Highlands, Malaysia: World Applied Sciences Journal. Tronh, Perak, Malaysia

[40] S. Mathuthu, K. Nwanga, & A. Simero(2000). ,Impact Assessment of Industrial and sewage effluents, Water quality of receiving marimba River. Harare Journal.

[41] D. C. McAvoy, P. Masscheleyn, C. Peng, S. W. Morrall, A. B. Casilla, J. M. U. Lim& Gregorio. ,Risk assessment approach for untreated wastewater using the QUAL2E water quality model,. Chemosphere, 52(2003) 55-66.

[42] G. Morrison, O. S. Fatoki, L. Persson, &A. Ekberg,. ,Assessment of the impact of point source pollution from the Keiskammahoek Sewage Treatment Plant on the KeiskammaRiver-pH, electrical conductivity, oxygen-

demanding substance (COD) and nutrients., Water SA, 27(4) (2001) 475-480.
[43] L.Mosley, S. Sarabject&B. Aalbersborg, B., Water Quality Monitoring in Pacific Island Counties. Handbook for water quality. Suva-Fiji Island. The University of South Africa Pacific (1st Edition)., (2004) 30-43.
[44] M. Mott and E. Associates Management of Industrial and Municipal effluents LWEMP Report (2001).
[45] M. A. Nadia, (2006). study on effluents from selected sugar mills in Pakistan: Potential environmental, health, and economic consequences of an excessive pollution load: Sustainable Development Policy Institute. Islamabad, Pakistan.
[46] NESREA., National Environmental Standards and Regulation Enforcement Agency. Regulations 96(65)(2009) the Federal Government Printer, Abuja, Nigeria.
[47] M. Nyanda., Report on the Study of Agrochemical use and handling in the Lake Zone, Tanzania.,(2000).
[48] D. Odigie&B. Fajemirokun,. Water Justice in Nigeria: Crisis or Challenge. International Workshop on Water Poverty and Social Crisis Agadir, Morocco, (2005) 12-15.
[49] A. E. Ogbeibu&P. U. Ezeunara. ,Ecological Impact of Brewery Effluent on the Ikpoba River, Using the Fish Communities as Bioindicators., Journal of Aquatic Sciences, 17(1)(2002) 35–44.
[50] O. A. Ogunfowokan&O. A Fakankun. ,Physico-chemical characterization of effluents from beverage processing plants in Ibadan, Nigeria., International Journal of Environmental Studies, 54(2)(1998) 145-152.
[51] A. I. Okoh, E. E. Odjadjare, E. O. Igbinosa,&A. N. Osode. ,Wastewater treatment plants as a source of microbial pathogens in receiving watersheds., African Journal of Biotechnology, 6(25)(2007).
[52] A. I. Okoh, T. Sibanda, &S. S. Gusha., Inadequately treated wastewater as a source of human enteric viruses in the environment. International journal of environmental research and public health, 7(6)(2010) 2620-2637.
[53] R. Perry, D. Green, and J. Maloney., Perry's Chemical Engineers Handbook. New York. McGraw Hill.,(2007).
[54] B. C. Punmia, A. K. Jain and K. Ashok.,Environmental Engineering -2 Wastewater Engineering (Including Air Pollution) Laxmi Publications (D) Ltd New Delhi Madras Jalandhar Hyderabad., (2007).
[55] A. Rim-Rukeh.,Physico-Chemical and Biological Characteristics of Stagnant Surface Water Bodies (Ponds and Lakes) Used for Drinking and Domestic Purposes in Niger Delta, Nigeria., Journal of Environmental Protection, 4(2013) 920-928.
[56] D. Scahill., Cow weight/cow meat ratio. They were retrieved from http://www.experts.about.com/q/Food-Science-1425/cowweight-cow meat.html.,(2003).
[57] E. M. Shaw., Hydrology in Practice (3rd ed.), London, Chapman, and Hall: (1994) 8-10
[58] H. W. Streeter and E. B. Phelps., A study of the pollution and natural purification of the Ohio River. III. Factors concerned in the phenomena of oxidation and reaeration. US Public Health Service, Bulletin No. (1994) 146.
[59] G. Tchobanoglous and E. D. Schroeder., Water quality: Characteristics, modeling, modification. Addison-Wesley, Massachusetts.,(1984).
[60] J. E. Umunnakwe, A. O. Nnaji, and P. I. Ejimmaduekwu,. ,Preliminary assessment of some physicochemical parameters during dredging of Nworie River,, Owerri. Pakistan Journal of Nutrition, 10(3)(2011) 269 – 273.
[61] L.A. Verheijen, H. M. Wiersema, D. L. Hulshoff, and J. De Wit., Management of wastes from animal product processing. Livestock and Environment, Finding a Balance. International Agriculture Center, Wageningen, The Netherlands.(1996).
[62] R. G. Wetzel (2001). Limnology-Lake and River ecosystems, 3d ed.: New York, Academic Press,1006.
[63] World Health Organization (WHO),. Guideline for Drinking Water Quality. 2nd Edition, Health Criteria and Other Supporting International Programme on Chemical Safety, World Health Organization, Geneva. 2(2004).
[64] C. Ukpaka, F. E. Ezeilo, Comparative Evaluation of Groundwater Parameters Simulation by Method of Linear & Quadratic Shape Function, SSRG International Journal of Civil Engineering 4(10) (2017) 1-26.
[65] WHO (Ed.). ,Guidelines for Drinking-water Quality,, Incorporating 1st and 2nd Addenda. World Health Organization Press, Geneva, Switzerland. 1(2008).
[66] Z. L. Zhu & D. L. Chen.,Nitrogen fertilizer use in China—Contributions to food production, impacts on the environment strategies., Nutrient Cycling Agroecosystems, 63(2002) 117–127.