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Modelling the Effects of Temperature and Biogenic Oil Effluent Concentration on Reaeration Coefficient of a Lake

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Abstract: **The study investigated the effect of temperature and concentration of biogenic oil effluent (BOE) discharged into a lake in River State, Nigeria. Standard method of physicochemical characteristics was used to analyze field parameters. The results indicated that the average temperature ranged between 26.2°C to 30.4°C** and **effluent concentration ranged between 98.2 mg/l to 986mg/l for mixture and raw effluent. The high value of Nitrogen (N), Phosphorus (P), Potassium (K), and Magnessium(Mg) were major components of biogenic effluent. It was observed that there was algae bloom and eutrophication due to high organic load in the lake. The re-aeration constant determined from the dissolved oxygen data from the study lake varies from 0.01d-^{1} to 0.19d-^{1} with an average of 0.062d-^{1}. The de-oxygenation constant obtained from laboratory determined from BOD_5 data was 0.44d$^{-1.}$ The self purification factor was 0.14. The study derived two models which predicted the re-aeration constant from measured field values. The correlation coefficient of the derived models for temperature and biogenic effluent were 0.914 and 0.978 respectively. The critical dissolved oxygen and critical deficit were 2.01 mg/l and 5.19mg/l respectively. The study recommended close monitoring of effluent discharge into the lake, effluent treatment and restriction of biogenic oil effluent discharged into a saver pit to minimize pollution into the lake.**

Keywords: **Effluent, physicochemical, biogenic, eutrophication, de-oxygenation, re-aereation, Pollution.**

1. INTRODUCTION

The negative effects of oil spill in the environment particularly in the Niger Delta have widely reported in the open literatures [1]Adeyinka, 2011 and [2]Okparanma, 2018. Today, there is increase in industrial effluent couple with flood, and agricultural runoff leading to increase the risk of pollution of surface and ground water [3]Oko et al, 2014; [4]Kola Olansanya 2014. These polluting discharges through natural and anthropogenic factors have serious effect on the water quality, the flora and the fauna [5]Ugbebor et al, 2012, [6]Okparanma et al, 2016. Water pollution is of interest to a water resources expert because drinkable water to local communities is scarce already and most interior or rural dwellers in developing countries rely on the surface water for the domestic uses including washing, bathing, dumping of body wastes. Discharge of untreated waste water directly causes undesirable change to the physical, chemical and biological characteristics of natural water bodies that may harmfully affect human [7]WHO, 1996, [8]Ikhile, 2011; [9]Akpan and Etim, 2015. [10]Ademorati, 1988 emphasizes that they is growing awareness of the need for effective treatment of various wastes before discharge into any public water body.

Today, the sensitivity of the people to pollution has increased with increased awareness, socioeconomic development values and ideologies [11]Obiukwu, 2000; [12]Ugbebor, et al 2011. [13]Chapman, 1992 said the waste discharge of high organic matter will lead to decrease in DO concentrations. The temperature of an area is crucial to water pollution problems. High water temperature will accelerate the growth of nuisance organisms, taste and odor problems are intensified. Low temperature somewhat decreases the disinfection efficiency [14]Salvato et al, 2003; [15]Chhatwal, 2012.

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The choice of a lake for this study is strategic as study further revealed impact of man's activities on the water quality on surface water, flora and fauna and the risk of exposure of the habitants living within the study environment. More so, the cost implication of lake and stream pollution is enormous, considering the public health, social and ecological impacts [16]Agbaire and Obi, 2009. Water quality studies in Nigeria are considered very important because Federal Ministry of Environment guidelines and standards for water pollution are being enforced [17]Federal Ministry of Environment, 1985.

The study lake is geographically located in a tropical rain forest with Niger flood plains and seasonal swamp forest (See figure 1) It is a fresh water swamp with farm land on dry land and patches of bush fallow with disperse oil palm, oranges, peer, coconut trees and numerous cash crops. During wet (rainy) season, it flows and empties into a flood plain. In dry season the lake is partially stagnant and the water is used as dry season fish harvest by local dwellers. Heavy rainfall is between the months of May and October. During the study there was no visible petrogenic oil spill, hence the study focuses on biogenic oil effluent discharge.

Figure 1: Showing Ahoada West LGA and Study Lake

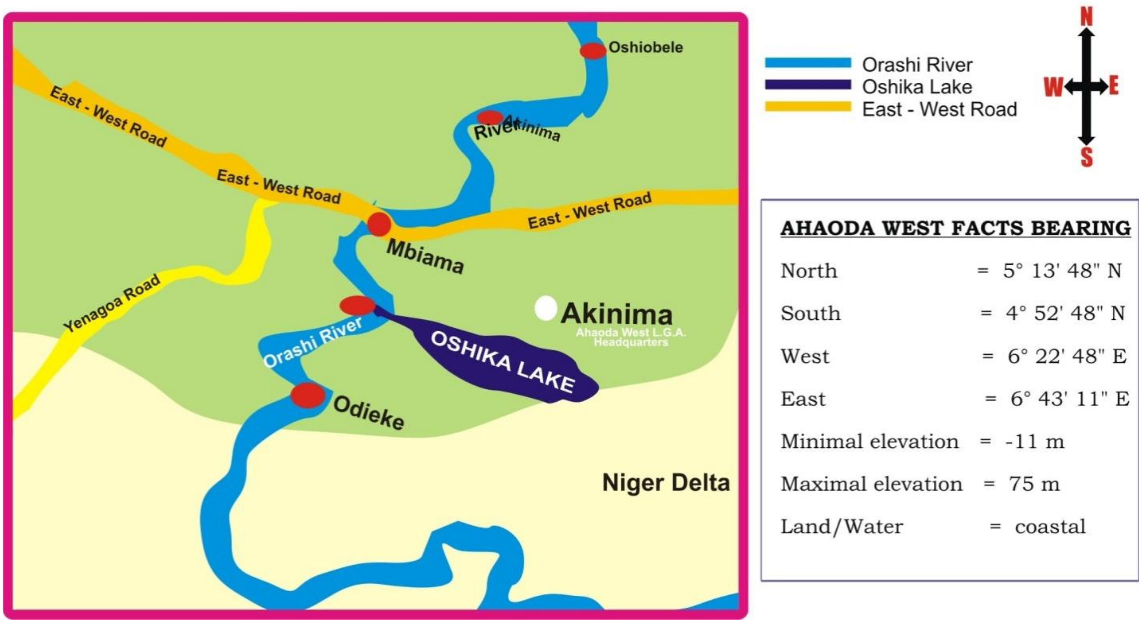

Figure 2: Showing study Lake and environs

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2. MATERIALS AND METHOD

The study spans a period of 12 months to acquire field data. Measurements and collection of samples were done from aboard a boat in wet season. Instruments such as thermometer, DO meter, turbidiometer and velocity meter were deployed for In-situ measurement of parameters including temperature, DO, turbidity and water flow velocity; and time interval between measurements were recorded. The laboratory analysis of BOD and COD were determined using standard methods. The reaeration (K_2) equation was generated for lake using

$$K_2 = \frac{In\ DO - InDt}{t} \quad 1$$

Where D_o is the initial deficit at upstream; D_t is the deficit at any point downstream, while t is time to travel between the two points. Two models for K_{21} and K_{22} were formulated using multiple regressions based on measured data. The parameters V, R, T and P represented the lake velocity, hydraulic radius, temperature and percentage biogenic oil effluent respectively. While a, a_1 and a_2, a_3, a_4, and b were constants obtained using regression equation. The Oxygen sag curve was derived using the street –Phelps model. The multiple regressions analysis was used to generate equations 2 and 3 which served as tools for predictions of K_2 values.

$$K_{21} = \frac{4.52 * 10^4\ V^{1.452}\ (1 + B)^{1.636}}{R^{4.575}} \quad 2$$

$$K_{22} = \frac{2.213E6 * V^{1.216} 1.8355^{-(T-20)}}{R^{4.847}} \quad 3$$

Where K_{21} is reaeration rate constant for BOE contaminated lake

K_{22} is reaeration rate constant for BOE contaminated lake with Temperature influence

3. RESULTS AND DISCUSSION

3.1 Results:

The results of mean parameters values at each sampled station for twelve months were expressed in Table 1.

Table 1: Mean parameters values at each station for 12 months.

STATIONS	pH	Temp (°C)	Cond. (Us//cm)	Salinity (%)	DO (mg/l)	BOD_5 (mg/l)	COD (mg/L)	Oil & Grease (mg/l)	Turbidity	TSS	TDS
CONTROL	5.458	27.921	26.583	0.645	5.075	9.471	13.300	0.020	4.667	17.092	60.808
1	5.413	27.763	28.875	0.918	3.642	12.943	19.442	0.571	5.842	20.075	66.048
2	5.458	27.575	28.583	1.105	2.608	16.275	26.617	0.602	6.992	22.842	72.260
3	5.418	27.613	28.675	1.219	2.171	15.808	24.267	0.701	6.450	20.808	71.904
4	5.385	27.554	28.992	1.189	2.192	15.421	23.275	0.632	5.825	18.983	71.050
5	5.381	27.800	30.142	1.067	2.486	14.493	21.854	0.603	5.775	17.238	68.125
6	5.304	28.142	31.208	0.938	2.850	13.629	20.758	0.488	5.142	15.692	65.567
7	5.292	28.017	30.096	0.835	3.093	12.996	19.108	0.465	4.792	15.021	62.792
8	5.315	27.908	29.725	0.765	3.339	12.394	17.492	0.395	4.583	14.467	60.158
9	5.314	27.775	29.363	0.668	3.600	11.947	16.542	0.260	4.292	13.871	57.292
10	5.368	27.733	29.175	0.468	3.967	11.453	15.800	0.240	4.133	13.300	53.633
11	5.358	27.675	28.867	0.399	4.429	10.673	14.496	0.173	3.942	12.854	51.179
12	5.377	27.717	28.742	0.388	4.858	10.052	13.275	0.194	3.833	12.317	48.158

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The results of temperature, effects of biogenic oil effluent (BOE) and predicted K_2 using derived models were shown. The variation of dissolved oxygen and reaeration coefficient (K_2) per day with respective to temperature were shown in figure 3 and 4.

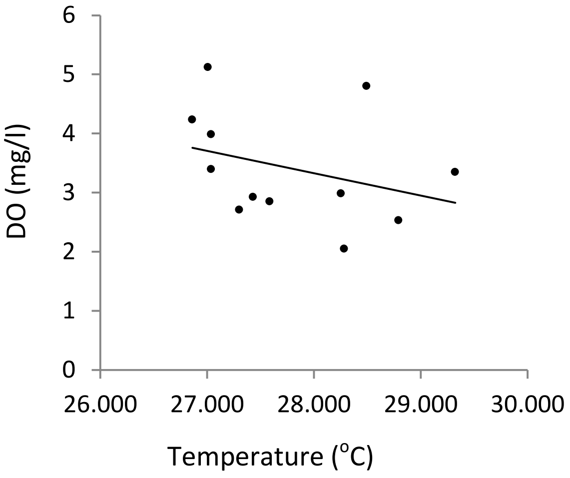

Fig 3: Variation of dissolved oxygen with temperature

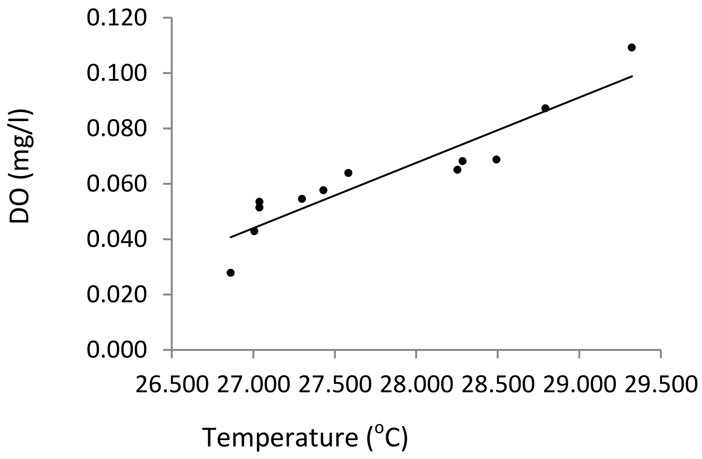

Fig 4: Variation of K2 (d-1) with temperature

The variation of K_2 observed with effluent concentration was indicated in figure 5.

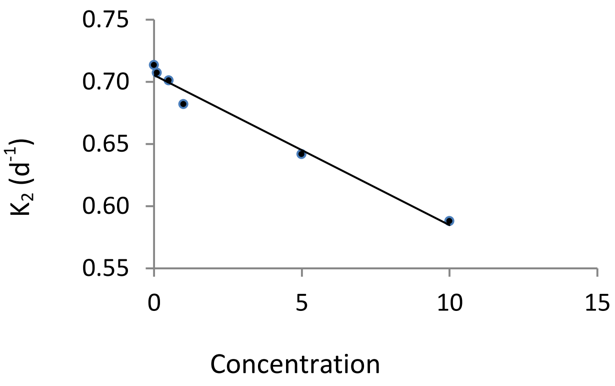

Fig 5: Variation of K_2 observed with concentration

The variation of D_t with distance for measured and predicted data using models which considered temperature and BOE were shown in equations 6 and 7

The reaeration coefficient (K_2) had a minimum value of $0.01d^{-1}$ and a maximum value of 0.19 d^{-1} with an average of 0.062 d^{-1}. The de-oxygenation constant K_1 was found to be 0.44 d^{-1}. From this, the purification factor f obtained by

$$f = \frac{K_2}{K_1}$$

was found to be 0.14. The measured dissolved oxygen saturation concentration was 7.2 mg/l at 28°C. At a distance of 1,600m, the critical dissolved oxygen was found to be 2.01mg/l. Hence the critical deficit is 5.19 mg/l.

The Oxygen deficit values obtained from measured K_2 and predicted K_2 using the Streeter – Phelps equation was plotted against distance as shown in figures 6 and 7.

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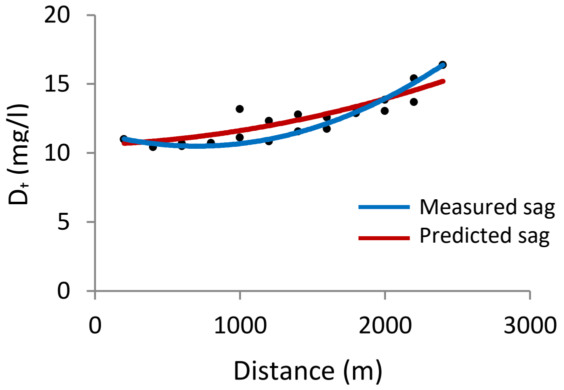

Fig 6: Variation of D_t with distance for measured and predicted data using model that considered temperature

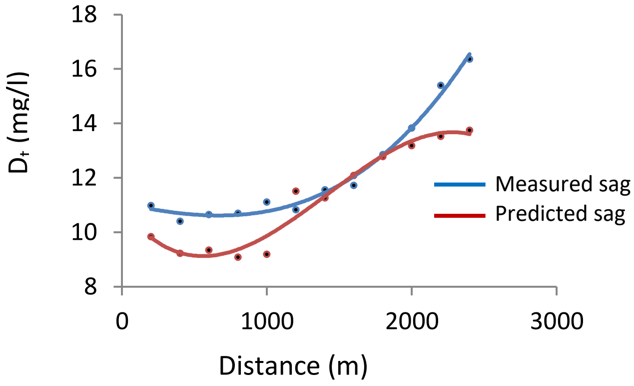

Fig 7: Variation of D_t with distance for measured and predicted data using model that considered BOE

3.2 Discussion:

The figure 2 indicated that as temperature increases, the DO content in the water reduces. Temperature also affects the reaeration K_2 as increase in temperature resulted in increase K_2 of the lake. The correlation coefficient between temperature and K_2 is 0.93.

At difference concentrations with increase in time and distance, there was self purification; however, increase in concentration of effluent resulted in increase in time of self purification.

The study indicated that increase in concentration resulted in decrease in K_2 values. The coefficient of correlation indicated that the BOE concentration was -0.99. The high negative correlation indicated that while BOE concentration reduces, K_2 values improved.

The predicted results of K_2 generated from multiple regression analysis indicated a coefficient of correlation of K_{21} as 0.978 with standard error of 1.7% while that of K_{22} was 0.914 with standard error of 3.6%. The Correlation coefficient of K_{21} and K_{22} was 0.913. The predicted reaeration coefficient values from these models were in good agreement with the observed values. A comparison of result indicated that the model that considered BOE had better correlation coefficient of 0.978.

Temperature also affects the rate of organic waste assimilation. Increase in temperature means increase in rate of oxidation, decrease in oxygen saturation capacity and rate of diffusion. Higher respiratory and metabolic rate due to increase temperature may destroy aquatic life. [18]Agunwamba, 2001. However, when temperature is crucial factor, the second model in equation 6 can be used since it has high correlation coefficient of 0.914. The low self purification factor was an indication that the water was polluted.

4. CONCLUSION

The study concentrated on monitoring the temperature and BOE effluent discharge to the study lake from local oil processing facilities which was the major source of pollution. Field measurements were carried out for 12 months; In-situ measurements and laboratory analyses were accomplished on pH, temperature, conductivity, salinity, DO, BOD_5, COD, oil and grease, turbidity, TSS and TDS (See Table 1). Models were derived using multiple regressions, and predictions were made to determine the status of the lake. The field temperature ranged between 26^{o}C to 31.^{o}C. The obtained result indicated that the BOD_5 values ranged between 1.6mg/l to 25.9mg/l along the lake. The reaeration coefficient, K_2 of the lake varied from 0.01 to 0.19 and self purification factor was 0.14 which indicated that the lake was polluted as at the study period. It was observed that there was algae bloom and eutrophication due to high organic load in the lake, causing physical, chemical and biological changes which deteriorate the water quality (Chhatwal, 2012).

The findings from the study will help develop impact control strategies including criteria for compliance, pollution monitoring and future treatment plan to mitigation the damage caused by direct discharge of untreated effluent into the lake.

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