

Development of Multiple Regression Model in Predicting the Dissolved Oxygen Deficit of Ntawaogba River

ABSTRACT

This study developed a multiple regression model for predicting the dissolved oxygen deficit for Ntawaogba River in Port Harcourt, Rivers State Nigeria. The instrument used for field sampling includes 1L sample container, Garmin GPS, EXTEC water equipment/Horiba, BOD bottle, Floaters, Measuring Tape, Stop watch, Ice chest and sample log book. Ten samples were collected along the river stretch at distance of 100m apart. Water quality analysis on the samples showed that ammonia and total coli form counts were higher than Federal Ministry of Environment recommended limits and the dissolved oxygen value ranges from 3.65-5.6mg/l. The computed deoxygenating rate constant was 0.38 and reaeration rate constant was 0.99. The Fair ratio, "f" for the river was 2.55; the dissolved oxygen (DO) deficit at initial time was 3.85mg/l and at critical time ($1.72d^{-1}$) the critical deficit was 2.48mg/l respectively. Multiple regression model was developed for dissolved oxygen deficit of the study River using appropriate excel software; considering BOD, temperature and river flow with constant b_0, b_1, b_2, b_3 to be 2.690293, 0.899899, -0.16754, and 0.042823 for respective sample points down the river at any point. These results indicated that the River is polluted and the fluctuation in DO values was attributed to constant waste discharges into the river from various sources and the hydraulic condition of the River. The study recommended that waste discharge into the River should be discouraged and the river should be monitored to mitigate further degradation.

KEYWORDS: Regression model, Deoxygenating rate, Excel software, Reaeration rate, Hydraulic condition.

1. INTRODUCTION

Naturally, rivers have abilities for self-purification upon introduction of contaminants. This self-purification capacity (otherwise called assimilative capacity) however, is limited by many factors such as waste loading, inherent river conditions, climatic factors and physical conditions, just to mention a few (Obinwanne et al, 2015; Chandravathi and

35 Resmi, 2013). Thus, continuous discharge of untreated waste into a river may
36 overstress it beyond its tolerance limits with deleterious effects on such river.

37 It therefore means that the assimilative capacity of the river should be closely monitored
38 to ensure it does not exceed its ability to safely receive wastes that are being disposed
39 in it and these can be fully studied by checking the dissolved oxygen content in the
40 water body.

41 Many rivers and water bodies in developing cities suffer greatly from poor waste
42 management practices in the area (Onojake and Abrakasa, 2012). Waste from various
43 sources including but not limited to domestic, commercial and industrial origins are
44 being discharged into canals, drainage systems and rivers serving as ultimate waste
45 receptacles (Olorodeet al, 2015). This practice has led to continual degradation of
46 surface water qualities and underground water contamination in many cases (Kahara,
47 2002). In surface water quality monitoring, there are some key parameters which
48 included the water pH, temperature, chloride, nitrate and ammonia, sulphate and
49 phosphate, dissolved oxygen, and biochemical oxygen demand which can provide vital
50 information on the overall health of the water body. Dissolved oxygen which refers to
51 the amount of gaseous oxygen dissolved in water and [Oxygen oxygen](#) is a basic
52 requirement for life, both in terrestrial and aquatic environments (Timmons et al, 2001).
53 It is an important parameter used to check the health of water bodies, such that the
54 level of dissolved oxygen in water can be used to decide whether or not the water is
55 polluted.

56 Typically, the concentration of oxygen present in water will depend largely on the water
57 temperature, organic load, water velocity for flowing water, wind speed, mixing in the
58 water, among others (Bergheim et al, 2006). For a water body to sufficiently support life,
59 a minimum of 4.0 mg/l dissolved oxygen is required. A very healthy aquatic environment
60 will have oxygen between 5.0mg/l and about 14.0mg/l at saturation. The discharge of
61 wastes into water bodies will cause a drop in the concentration of dissolved oxygen
62 (Omole and Longe, 2012). It then means that continuous discharge of such wastes will
63 further degrade the water quality by diminishing its oxygen content and making the

64 water unfit for its purpose. In water bodies (streams, lakes, rivers), there is a minimum
65 concentration of oxygen required to support living organisms.

66 The equation derived by Streeter and Phelps (1925) provides a useful tool for modelling
67 the oxygen content of a water receiving wastes, such that reliable information about the
68 health and assimilative capacity of the water can be ascertained (Omole, 2011; Longe
69 and Omole, 2008). Though the Streeter [and](#) Phelps equation is only applicable to point
70 source pollution and does not account for oxygen demand by sediment and loss of
71 oxygen through other means other than breaking down of organic matter. And the ability
72 for a river to self-purify itself is **dependent** on waste load, dilution, **and** temperature.

73 **2. STUDY AREA**

74 Ntawogba River is located in Port Harcourt, Rivers State of Nigeria. It lies on the
75 South-South geopolitical zone at latitudes 4°43'23" North and Longitudes 6°55'15" East
76 on the map of Nigeria (Obinwanne and Okpoko, 2015). It is one of the water bodies in
77 Port Harcourt and Niger Delta that serve as receptacles for various kinds of wastes
78 generated in the region (Fabian and Kingdom, 2012). The practice of waste disposal
79 arising from lack of proper waste management systems has made many rivers **in Port**
80 **Harcourt metropolis in rivers state Nigeria**, to be more vulnerable to pollution from
81 municipal wastes, among other waste sources (Ogan, 1998; Moffat and Linden, 1995).

82

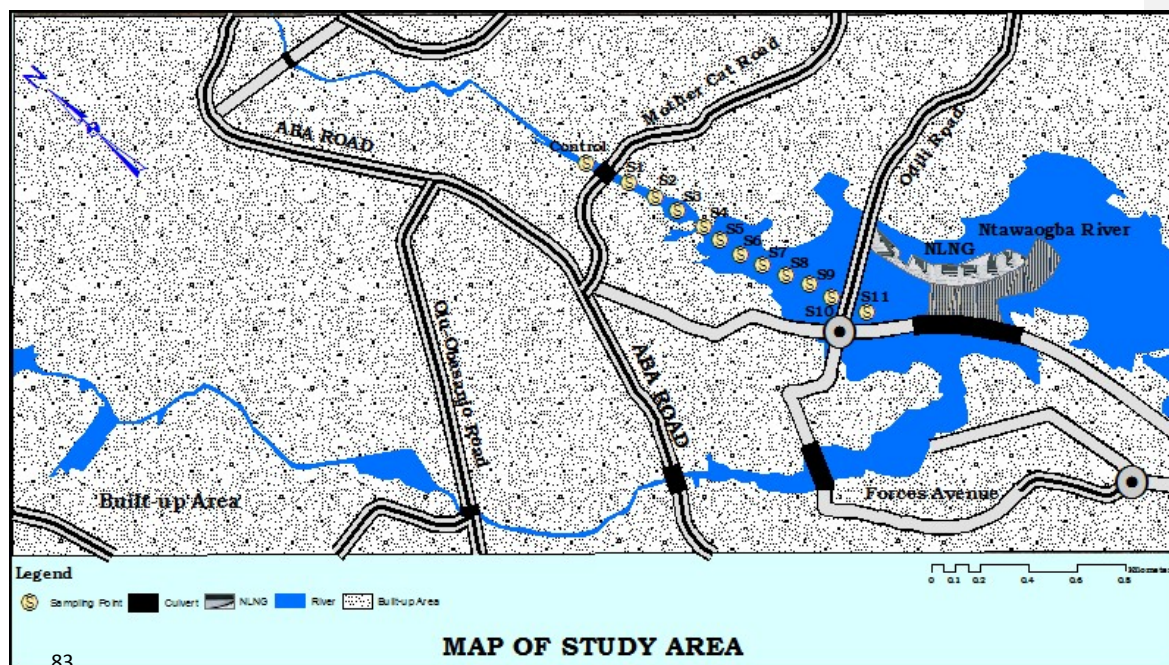


Figure 1: Map of the Study area in Rivers State, Nigeria.

2. METHODOLOGY

Study of the Ntawagba River was conducted within a distance of 1km. and the research scope covers samples collection for 10 points at 100m interval distance with the first point as control upstream, using scientifically approved methods, American water works association (AWWA, 1997). The distance of sampling was measured using a Global Positioning System (GPS). The study parameters under study include: pH, BOD, COD, DO, electrical conductivity, ammonia and temperature which was compared with Federal Ministry of Environment Standard. Ten water samples were collected along the stretch of the river at an interval of 100 meters apart using scientifically approved methods, American water works association (AWWA, 1997). The distance of sampling was measured using a Global Positioning System (GPS).

The sampling points were labelled on a sample log as PA, PB, PC...PJ to represent Point A, Point B, and Point C...Point J for the ten points, respectively.

Comment [U1]: In all text, the letters should be the same, for parameters

98 The field parameters measured include temperature, pH, turbidity, dissolved oxygen
 99 (DO), salinity and electrical conductivity (EC) using EXTEC water meter and Horiba. On
 100 completion of the in-situ measurements, samples were collected in appropriate sample
 101 containers and preserved at 4°C in ice chest to maintain the integrity while being
 102 transferred to the laboratory.

Comment [U2]: ?

103 Flow velocity, width and water depth were measured at each point to determine the
 104 respective average values with the use of floaters, stopwatch and measuring tape.

105 Study of the Ntawagba River was conducted within a distance of 1km. and the
 106 research scope covers samples collection for 10 points at 100m interval distance
 107 with the first point as control upstream. The study parameters under study
 108 include: pH, BOD, COD, DO, Electrical conductivity, Ammonia and Temperature
 109 which was compared with Federal Ministry of Environment Standard.

110 De-oxygenation rate constant is the rate at which oxygen is depleted in the water. It is
 111 expressed per day as written in Equation one, computed using the Thomas slope
 112 graphical method.

113

$$114 \quad (t/y)^{1/3} = (K_1 L_o)^{-1/3} + K^{2/3}/6L_o^{1/3}, \quad \text{Eqn. 1}$$

115 where t = - time at sample stations (day)

Comment [U3]: Not =, but -

116 y = - BOD that has been exerted (unit?)

117 K = - reaeration rate constant to base 10, (unit?)

118 L_o = - Ultimate ultimate BOD, (unit?).

119 From graph

Comment [U4]: All next parameters- unit?

$$120 \quad K_1 = 2.61 \frac{B}{A} \quad \text{Eqn. 2}$$

121 where B = slope of the best fit line

122 A = intercept of the best fit line on the ordinate axis.

$$123 \quad L_o = \frac{1}{2.3K_1 A^2} \quad \text{Eqn. 3}$$

124 Correcting deoxygenating rate constant to any other temperature, the equation four is
 125 applied

126

127 $K_1 = K_{10} \theta^{(T-10)}$ Eqn. 4

128 Reaeration rate constant by O' Connor and Dobbins was used to analyses the K_r of the
129 river using the stream conditions.

130 $K_r = \frac{3.7V^{1/2}}{H^{3/2}}$ Eqn. 5

131 where V=average velocity of the stream

132 H=average depth

133 Multiple regression model was developed to estimate the dissolved oxygen deficit at
134 each point downstream. By relating with multiple factors (BOD, DO and Discharge). A
135 method proposed by Churchill and Buckingham (1956).

136 Correction equations based on measurement taken at maximum stream temperature
137 and minimum flow is gotten using:

138 $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ Eqn. 6

139 where Y=DOD, mg/l; X_1 =BODs, mg/l; X_2 =stream temperature; X_3 =Stream stream
140 Discharge, m³/s; b_0, b_1, b_2, b_3 are constants derived from field parameters.

Comment [U5]: T or t – the same in all text

Comment [U6]: D or d

141 3. RESULTS AND DISCUSSIONS

142 The sample collected from the Ntawaogba River was analysed. The mean data
143 temperature at the time sampling was 28°C. The results of the analysis of the physical,
144 chemical and biological parameter are also presented in Table 2. Also present, was the
145 results of the velocity, width, and depth measured and their respective averages.

Comment [U7]: Befor 2 is 1, what about Table 1?

146 Table 1: Velocity, Widthwidth, and Depth depth Measurementmeasurement

SAMPLE POINT	Distance (m)	Time (s)	Velocity (m/s)	Depth (m)	Width (m)
Point A (CONTROL)	100	270	0.37	2.44	12
Point B	100	280	0.36	2.23	11
Point C	100	290	0.34	1.98	14

Point D	100	275	0.36	2.26	12
Point E	100	260	0.38	3.10	10
Point F	100	285	0.35	1.80	9
Point G	100	240	0.42	3.50	11
Point H	100	250	0.40	2.50	12
Point I	100	260	0.38	2.60	14
Point J	100	270	0.37	1.85	16
Mean		268	0.37	2.42	12.1

From Table one1, the average velocity, width and depth of the water are:

Comment [U8]: Not from Table, but from measurements

Average velocity = 0.37m/s

Average depth = 2.42m

Average width = 12.1m

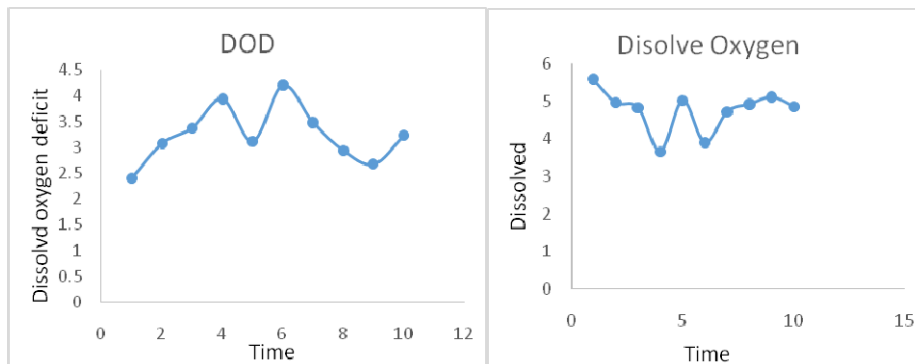
Table2: Field Data Analysis for Ntawagba River

PARAMETERS	Point A	Point B	Point C	Point D	Point E	Point F	Point G	Point H	Point I	Point J	FMEEnv Standard
pH	7.19	6.89	7.51	6.54	6.64	6.83	6.55	6.77	6.8	6.67	6.5-8.5
Temperature. °C	28.3	28	28.6	28.7	27.5	28.7	27	27.89	28.6	26.9	20-30
Electrical Conductivity, μ S/cm	207	211	203	210	211	212	213	159	160	175	100
TDS (mg/l)	110	112	108	111	112	112	113	84	85	93	250
Turbidity, (NTU)	3	2	3	1	2	5	3	3	4	3	5
TSS (mg/l)	9	7	11	4	7	11	9	19	6	11	10
Dissolve Oxygen (mg/l)	5.6	4.97	4.84	3.65	5.03	3.89	4.73	4.93	5.12	4.86	7.2
BOD, (mg/l)	4.4	8.2	8.55	9.12	8.11	9.65	8.26	7.89	7.52	8.30	<10
COD, (mg/l)	12.35	14.42	14.62	15.76	14.11	15.26	15.03	13.75	12.38	14.25	5
Salinity (as Cl) (mg/l)	28.36	31.91	24.82	28.36	21.27	24.82	24.82	21.27	28.36	21.27	<2000
Nitrate, (mg/l)	1.869	1.869	1.913	1.978	1.848	1.826	1.869	2.195	1.978	1.482	50
Sulphate, (mg/l)	4.7	5.334	5.334	5.017	5.228	6.017	5.595	4.011	5.817	6.228	150
Phosphate, (mg/l)	1.664	1.419	1.313	1.672	1.558	1.504	1.648	1.439	1.873	1.538	0.3

Ammonia (mg/l)	5.216	4.398	3.381	4.888	4.782	5.1	4.846	3.276	3.381	4.782	<2
THC, (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
Copper, (mg/l)	0.033	0.053	0.064	0.041	0.056	0.045	0.062	0.059	0.078	0.033	-
Zinc, (mg/l)	0.024	0.032	0.041	0.036	0.03	0.039	0.051	0.084	0.041	0.042	
Total Iron, (mg/l)	0.558	0.651	0.495	0.713	0.718	0.682	0.776	1.461	0.713	0.651	20
Manganese, (mg/l)	0.019	0.028	0.026	0.028	0.025	0.019	0.019	0.028	0.026	0.028	150
Lead, (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1
THB x10 ⁴ CFU/ml	3.1	1.7	3.5	2.3	1.6	2.8	3.6	2.3	1.8	2	-
TF x10 ² CFU/ml	0.9	0.3	1.1	0.4	0.6	1	1.2	0.8	0.4	0.6	10
TF x10 ²	0.9	0.3	1.1	0.4	0.6	1	1.2	0.8	0.4	0.6	-

154

155 Result obtained from Ntawaogba river was used to analyze the dissolved oxygen level
156 at each sample point downstream with major pollutant **sources** which are open drains,
157 domestic waste, slaughter waste, excretes,.



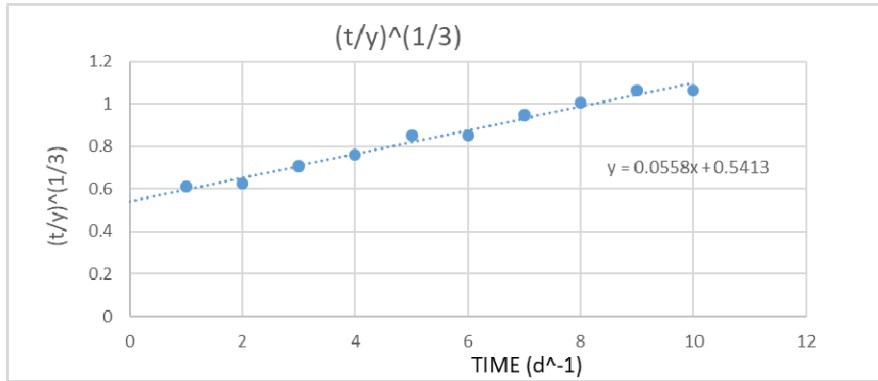
158

159 Figure 2: Plot of DOD against time Figure 3: Plot of Dissolved Oxygen against time

160

161 Deoxygenating Rate Constant for Ntawaogba River was computed using the graphical
162 method as shown in fig 4.

Comment [U9]: Style? Units, without names in Figures, etc. please see Dissolve?



163
 164 Figure 4: Graphical determination of deoxygenating rate constant
 165 From the graph, the deoxygenating rate constant (K_1) was computed using equation 2
 166 with slope 0.06 and intercept 0.54

167 $K_1 = 2.61 \frac{0.06}{0.54}$ Eqn. 7

168 $K_1 = 0.26$ Eqn. 8

Comment [U10]: They are not new Eq. They were in Methodology showed. Should be better to complete results in Table

169 Correction to temperature at 28°C using equation 4, deoxygenating rate constant (K_1)

170 $K_1 = K_{10} \theta^{(T-20)}$ Eqn. 9

171 $K_1 = 0.38$ at 28°C Eqn.10

172 With an average velocity of the River (V) to be 0.37 and average depth of the river (H)
 173 which was 2.42m as stated in equation 5 the Reaeration Rate Constant (k_2)

174 $K_2(T) = 3.93V^{1/2}/H^{3/2}$ Eqn. 11

175 $K_2 = 0.81 d^{-1}$ Eqn. 12

176 Correcting to temperature of 28°C at sampling time using

177 $K_T = 0.81(1.024)^{(28-20)}$ Eqn. 13

178 $K_2 = 0.98 d^{-1}$ At 28°C Eqn. 14

179 The self-purification factor f is

180 $f = \frac{A}{A_1} = 2.55$ for Ntawaogba River. Eqn. 15

181 Appropriate tool in Excel was used to generate the constant in the multiple regression
182 model and was analyzed across the stream, considering the various parameters as
183 stated in the table two. Result are tabulated in table 3 and also represented in (fig 5).

184 Table 3: DOD Measured and Predicted Value at different sample Point

DOMEASURED (mg/l)	DOD(mg/l)	BOD (mg/l)	Temperature	Flow Q(m3/s)	predicted	sum.square
5.6	2.411	4.4	28.1	10.84	2.406304426	2.2048E-05
4.97	3.041	8.2	27.9	8.76	3.079904598	0.00151357
4.84	3.171	8.55	28.2	9.56	3.378774989	0.04317045
3.65	4.361	9.12	28	9.86	3.93820945	0.17875185
5.03	2.981	8.11	28	11.92	3.117579923	0.01865408
3.89	4.121	9.65	28.2	5.68	4.20275165	0.00668333
4.73	3.281	8.26	27.69	16.04	3.480871294	0.03994853
4.93	3.081	7.89	27.89	12.00	2.941325832	0.01950887
5.12	2.891	7.52	28	14.00	2.675578718	0.04640633
4.86	3.151	8.3	28.1	10.96	3.230691984	0.00635081
						0.36100987

185

186 As stated using multiple regression in equation 6;

187 $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ Eqn. 16

188

189 where Y=DOD, mg/l; X_1 =BODs, mg/l; X_2 =stream temperature; X_3 =Stream Discharge,
190 m3/s; b_0, b_1, b_2, b_3 are constant derived from field parameters

191 $b_0 = 2.690293; b_1 = 0.899899; b_2 = -0.16754; b_3 = 0.042823$ Eqn. 17

192 $Y = 2.690293 + 0.899899 X_1 - 0.16754 + 0.042823 X_3$ Eqn.18

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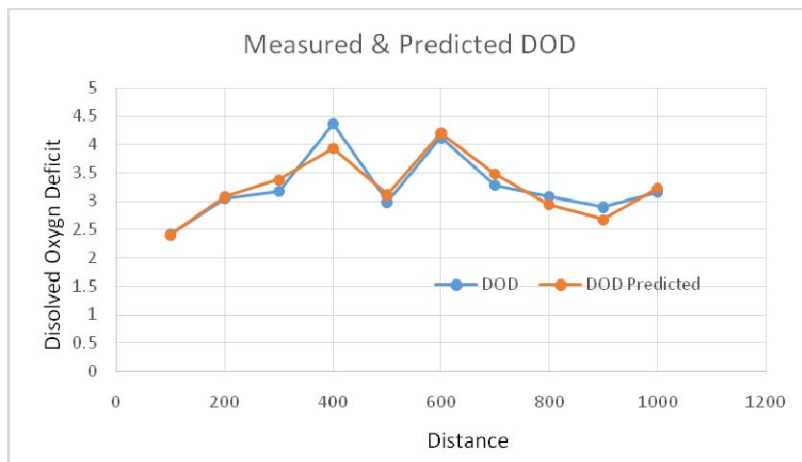


Figure 5: Plot of DOD Measured and Predicted against Distance

4. DISCUSSION

From table one it will be seen that the average width, depth and velocity for sample point A –J was found to be 2.42m, 12.1m and 0.37m/s respectively.

As presented in table 2, which showed the analysis result on various physiochemical parameters for the various sample point, Water-quality analysis on the samples showed that most of the measured parameter falls within the recommended limit except for parameters like turbidity, BOD, COD, and DO in specific sample points (Table 2). High turbidity of river water as shown in table 2 is harmful because it provides hiding place for harmful microorganisms and such microbes can be consumed by people who drink such water thereby result in epidemics. High turbidity as observed in study river is unacceptable for aesthetic reasons (Nathanson, 2006). Turbidity may reduce sunlight penetration into the water body thereby slowing down photosynthesis. Chemical parameters including BOD and COD higher than the maximum limits by Federal Ministry of Environment standards signified that there was high organic load in the river. Low DO as observed at some points may cause death of aquatics life. While ammonia above the recommended maximum limit of 2mg/l, indicated that water is contaminated with sewage from continuous defecation along the stretch of the river. This basically fast tracked algae growth which subsequently degrade the water quality and result in eutrophication.

The field result indicated that there was a significant oxygen deficit at point 4 and 6 in Fig. (3) due to channel discharge, domestic waste, and slaughter waste discharge. The

Comment [U11]: Point 3 was Result and discussion

Comment [U12]: It was written in results, this is not discussion

Comment [U13]:

217 de-oxygenation rate constant (K_1) was calculated using equation 2 from BOD data and
218 adjusted in accordance with the corresponding curves as presented in Fig 4. Using the
219 graphical method proposed by (Thomas, 1950).

220 Using Microsoft excel based programme, the constant b_0, b_1, b_2, b_3 was generated for the
221 regression model and was analysed across the stream considering the various
222 parameters as stated in equation 6 and table 3. Dissolved oxygen deficit predicted and
223 measured against distance was plot and represented in Fig. 5.

Comment [U14]: DISCUSSION IS VERY POOR, it was written the same what in results

224 The result of the analysis got from the field showed that the reaeration coefficient (K_2)
225 under stream conditions was found to be 0.99. The deoxygenating constant (K_1) using
226 the Thomas slope graphical method was computed to be 0.26. K_1 and K_2 were
227 important parameters because they help select curve that best fit rivers conditions at the
228 time and season of measurement. The river K_1 and K_2 values signified that the organic
229 load into the river was high due to discharge of sewage, municipal and domestic waste.
230 Also, the re-oxygenation co-efficient (f) of Ntawagba river was 2.55. This indicated that
231 the purifying capacity of the river system was low in relation to the received
232 contaminants, though Ntawagba river during the period of study falls under the typical
233 values of receiving natural water body of large stream with moderate velocity. (Fair et al,
234 1971).

Comment [U15]: It could be references from 2000 and more

235 Also, it was observed that the average river temperature was 28°C. High temperature
236 means increased oxidation, increase BOD exertion and increased rate of organic waste
237 assimilation. (Ugbebor, et al, 2012).

238 5.1 CONCLUSION

Comment [U16]: Why 5.1?

239 The combination of relatively low DO value which ranges from 3.65 to 5.6 along the
240 river, high BOD and ammonia as observed in Ntawagba river indicated that the river is
241 polluted from multi source discharges (e.g storm water runoff, sewage, slaughter
242 waste, municipal waste, domestic waste and untreated effluent) all loaded with organic
243 matters.

244 The research enhanced the pollution dynamics of Ntawagba river and therefore
245 advised that proper environmental monitoring and water resource management should
246 commenced by lead agencies in Port Harcourt, Rivers State of Nigeria to avoid further
247 organic over load of the river which could increase the negative environmental impact of
248 the river and increase the health risk of neighbouring communities.

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