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Assessment of Saturated Dissolved Oxygen, Temperature, and Total Dissolved Solid of Nworie River Using Multiple Regression Model

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Abstract
The increase of oxygen deficit in rivers used for irrigating agricultural land, aquaculture, and domestic purposes is of great concern in Nigeria. To determine this along Nworie River, physicochemical and biological water quality analyses were conducted at three random locations namely: Amakohia/Egbeada bridge road where biodegradable and non-biodegradable wastes are discharged; Assumpta/Holy Ghost College Road where municipal waste and sewage are discharged into the river; and Umezurike Hospital Road where household and medical wastes are discharged. The dissolved oxygen, temperature, and total dissolved solids from the laboratory analyses were used to show the relationship among physicochemical parameters using multiple regression models. The results of the estimated dissolved oxygen obtained for the three studied locations were 6.477mg/l, 5.832mg/l,and 3.992mg/l, respectively. These results were correlated with the observed value and a correlation coefficient, $R^2$of 0.9992 was obtained. The high positive correlated result of the observed value to the laboratory dissolved oxygen implied that the model provides a good approximate solution in determining physicochemical parameters in water.

Keywords: Physicochemical, Temperature, Dissolved-oxygen, Regression, Total dissolved solid.

1.0 Introduction

The global water quality crisis is a pressing issue that our world is currently facing. The continuous growth of urbanization and population along with rapid industrialization and intensifying food production, have all created a significant strain on water supplies. Unfortunately, this has resulted in an increase in the unrestricted or illegal discharge of contaminated water, both within and outside national borders. This poses a serious threat to human health and well-being worldwide, and it has significant implications for our efforts to fight poverty and maintain the health of our most productive ecosystems. Although there are various factors contributing to this problem, it is clear that freshwater and coastal ecosystems worldwide are being impacted.(Roy et al., 2011).

A community's health status is impacted by the quality and quantity of water that is accessible to it (Nwidu et al., 2008). The Nworie stream in Owerri is currently experiencing significant changes due to the growing industry, ongoing urbanization, and population increase. Ever since it became the capital of Imo state in 1976, Owerri and the surrounding areas along the Nworie River have witnessed substantial demographic, agricultural, and industrial growth.(Ibe and Sowa., 2002). However, with these challenges enumerated, there is a need to determine the relationship of physiochemical parameters in Nworie River for comparative analysis using mathematical equations (model) to assess as well validate the relationship of a contaminant to another. Every body of water in the environment contains dissolved salts in ionic forms. Different species, though, are present in different numbers and concentrations. Industrial and domestic effluents, agricultural waste, radioactive waste, thermal and oil pollution, as well as inputs through rainwater, water/rock interaction, climate, topography, and geology all affect the concentration of dissolved salts in water.(Verla et al., 2020)

A statistical technique called multiple linear regression (MLR) utilizes multiple input factors to predict the outcome of a response variable. MLR is used to determine the relationships between two or more variables(Uyanık, and Güler, 2013). Several studies have shown mathematical modelsto predict the relationship between an independent variable and a dependent variable. Tong et al. (2002) studied the Modeling of the relationship between land use and surface water quality. Their research attempted to use a comprehensive approach to examine the hydrologic effects of land use at both a regional and a local scale. Yap et al. (2006) studied variations of a benthic species called Oligochateas and physicochemical parameters of water in a river in Malaysia from March 1998 to February 1999 and showed that there has been a negative correlation between density and distribution of this benthic macro-invertebrate and DO and PH, and a positive correlation with electrical conductivity, BOD, NO_3, NH_3, TSS, COD, Cc and Zn. Monk et al. (2007) reviewed the 22-year long-term statistics of samples collected from 14 rivers in England. They computed BMWP, EPT, and Life Score biotic indices and studied their variations with respect to changes in Indicators of Hydrologic Alteration (IHA) and observed the strongest relation between biotic indices and hydrological parameters in frequency and intensity of current flow groups.

The main objective of this study is to use the MLR approach to determine or predict the relationship of some physiochemical parameters in the Nworie River. The specific objectives therefore include:

i. A pollution watch of the surface water contaminant in Nworie River. This entails sampling and analyzing surface water for quality investigation of water

ii. Establish a relationship between dissolved oxygen, total dissolved solids (TDS), and temperature of the stream

This research hopes to help environmental engineers, soil and water engineers, water resources engineers and a host of other engineers in monitoring the environment and natural changes occurring in local, regional or global watersheds and/or changes in aquatic ecosystems forced by anthropogenic factors.

Although quite a lot of parameters were discovered at the end of the physiochemical analysis of the water samples, the scope of the study only covers the relationship between dissolved oxygen, TDS, and temperature in the stream. This relationship could be applied from the point of effluent discharge to the downstream along the river.

2.0 Materials and Methods

2.1 Materials

The material used during the research includes:

Materials for collection of water samples from the study area e.g., 6 plastic containers with the label; Two pairs of Staff, Distance measuring tape and measuring rod; stopwatch; The laboratory Equipment: (pH meter, Suntex model TS-2, Multiparameter Bench Photometers HANNA Instruments (HI 83200), Comparator Instrument, Turbidity meter and handheld conductivity meter model HI 98302 (HANNA).

Apparatus used: Beaker, Measuring cylinder, round bottom flask, Hand glove, pipette, Wash bottle 0.45µm membrane and thermometer.

2.1.1 Sample collection

Samples of water and sediments were collected in the early hours of the day into five 10-litree 10-liter containers from these stations during July 2023. These samples were labelled, packed inside a container filled with ice cubes and transported to the soil and water laboratory of the Agricultural and Bioresources Engineering Department of the Federal University of Technology, Owerri, for analysis. Standard analytical methods were used for all the water quality analyses(APHA, 1992).

2.1.2 Sample location

Owerri is the capital of Imo State. it lies between latitudes 5°15-5°35'N of the equator and longitudes 6°55-7°15'E of the Greenwich Meridian(Amadi, 2017). The Map ofOwerri and the three sample locations are shown in Figures1 and 2. Figure 1 indicates that the terrain is depressed with a good road network.Figure 2 indicates the flow pattern ofthe Nworie River and the three sample locations, which were: Egbeada Bridge, Warehouse by Assumpta Bridge, and Umezurike Bridge. The distance from sample points1 to 3 is 6.14km.Nworie River is a first-order stream that runs about a 5km course across Owerri metropolis in Imo state, Nigeria before emptying into another river, the Otamiri River (Umunnakwe & Nnaji, 2011). It flows through some establishments that discharge their untreated waste into it. The river acts as a source of drinking water, fishing and other domestic uses for the inhabitants. Its watershed is subject to intensive human and industrial activities resulting in the discharge of a wide range of pollutants both organic and inorganic (Acholonu, 2016).There are two common climatic conditions in the area, which are: the rainy and the dry seasons. The rainy (wet) season is from April to October while the dry season starts in November to March. The average monthly temperatures are high throughout the year. A mean annual temperature of 32°C is typical of the area.

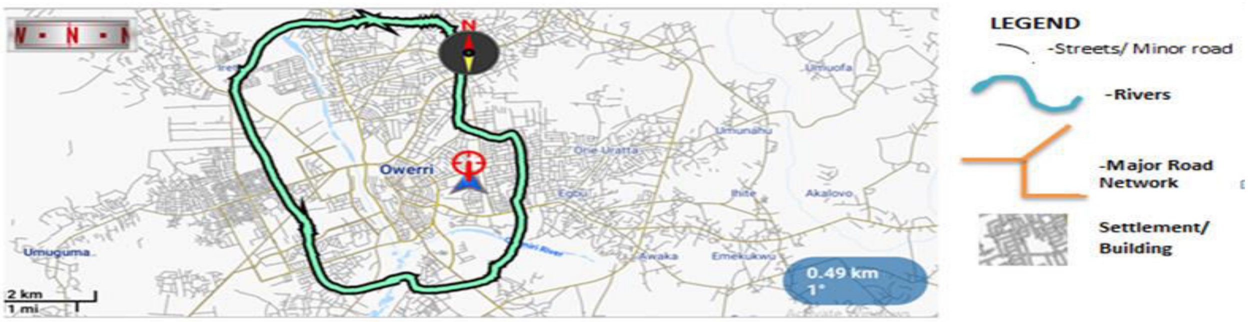

Figure 1: Map of Owerri Municipal showing streets, roads, settlements and river distribution.

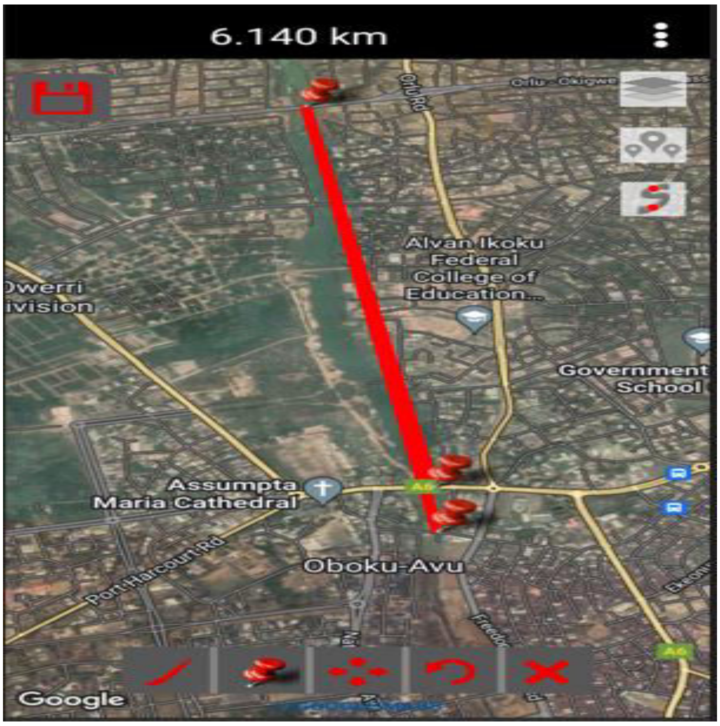

Figure 2: Map of the three Sample locations (Egbeada, Assumpta Road Bridge and Umuzurike Road Bridge (Source: Google Map).

Two characteristics of water samples were recognized during the experimental testing of water samples. They includePhysical andChemical characteristics.
The physical characteristics included: colour, taste, odour and turbidity. On the other hand, the chemical characteristics comprise total dissolved solids, organic matter, hardness, alkalinity, acidity, pH, nitrogen as nitrate, nitrites, chlorides, sulphates, oxygen absorption and heavy metals. Also,the BOD test, DO test as well andCOD analysis were carried out in the laboratory.
The analyses of the parameters were carried out according to the methods outlined in the instruction manual of the HI 83200 multiparameter bench photometer for laboratories.

2.2.1 Experimental method I (physical)

The analysis under physical experiment was carried out using the method outlined in the instruction manual of the HI 83200 Multiparameter Bench Photometer for laboratories.

2.2.2 Experimental method II (chemical)

The analysis under chemical experiment was also carried out using the method outlined in the instruction manual of the HI 83200 Multiparameter Bench Photometer for laboratories. pH of Water; Alkalinity; Free chlorine; Total Chlorine; Dissolved Oxygen; Sulphate; Nitrate; Copper; Calcium Hardness; Magnesium Hardness; iron; as well as other heavy metals were analyzed.

3.0 Results and Discussion

3.1 Physicochemical results

The result of the physicochemical analysis is presented in Table 3.1 which shows the three sample locations, the WHO standards for parameters, the mean concentrations and their standard deviations. The study also assessed the level of heavy metals and contaminants in the surface water of Nworie River at three sample locations during July 2023, using the multiparameter bench photometer.

Table 3.1: Physicochemical analysis result

Parameter	WHO Standard	Mean	Range	Amakohia bridge road	Assumpta, Holy Ghost College Road	Umezurike Hospital road	Standard Deviation
pH	6.5-8.5	7.133	7.1-7.3	7.1	7.0	7.3	0.0694
Alkalinity (mg/l)	200	10	5-15	15.0	10.0	5.0	5.0
Temperature	ambient	24.67	24-25	24.0	25.0	25.0	0.577
Colour of Water in PCU	15	568.67	431-640	431	640	635	119.249
Conductivity (μs/cm)	100	111.3	60.5-141	60.5	141.0	132.50	44.23
TDS(mg/l)	250	53.667	40-73	40	48	73	17.21434
turbidity NTU	50	114.833	5-65	63.50	146.30	134.70	44.83273
BOD(mg/l	40	3.233	2.9-3.5	3.30	3.50	2.90	0.305505
DO(mg/l)	4.0	5.9	5.4-6.5	6.50	5.80	5.40	0.556776

Nitrate(mg/l)	40	78.67	58.5-117.5	60	117.45	58.5	148.891
Nitrite (mg/l)	40.	17.33	10.0-21.0	21	21	10	1.931
Sulphate (mg/l)	250	5.6	1.8-10	1.8	10	5	4.133
Hardness (mg/l)	150	53.667	39.5-64.2	39.50	57.30	64.20	12.74454
Iron(Fe)(mg/l)	0.3	0.1967	0.12-0.25	0.22	0.12	0.25	0.0681
Manganese mg/l	0.5	0.5	0.2-0.8	0.2	0.5	0.8	0.3
Calcium (mg/l)	70	90	80-100	100	90	80	10
Zinc (mg/l)	5	0.5533		0.55	0.43	0.68	0.12503
Copper (mg/l)	1.0	0.3333	0.2-0.5	0.2	0.3	0.5	0.152753
Lead (Pb)	0.05	0.083	0.05-0.12	0.05	0.12	0.08	0.0351
Calcium Hardness (mg/l)		0.4267		0.48	0.20	0.60	0.024326
Chlorine(mg/l)	200	11.233	9-11.5	9	13.2	11.5	2.11266

The Multiple Regression model showing the relationship between saturated dissolved oxygen, temperature and total dissolved solid of Nworie River is given in Equation (3.1).The saturation DO value for freshwater depends upon the temperature and total dissolved salts present in it.

This relationship can be expressed as:

$DO = c\,Temp.^{a1}\,TDS^{a2}$ (3.1)

Where,

DO = Dissolved oxygen which is the dependent variable,

Temp. = Temperature, an independent variable,

TDS = Total Dissolved Solid, an independent variable

C, a_1, and a_2 are constants.

Equation (3.1) was then linearized or transformed to multiple regression models by taking the logarithm of both sides and given as:

$$\log DO = \log C + a_1 \log Temp. + a_2 \log TDS \quad (3.2)$$

Thus, the estimates of coefficients, c, a_1 and a_2 can be obtained by setting:

$$y = LogDO;\ a_0 = \log C\,;\ x_1 = \log Temp\ and\ x_2 = \log TDS$$

i.e. $y = a_0 + a_1x_1 + a_2x_2$

$$\sum y = a_0 n + a_1 \sum x_1 + a_2 \sum x_2 \quad (3.3)$$

$$\sum x_1 y = a_0 \sum x_1 + a_1 \sum x_1^2 + a_2 \sum x_1 x_2 \quad (3.4)$$

$$\sum x_2 y = a_0 \sum x_2 + a_1 \sum x_1 x_2 + a_2 \sum x_2^2 \quad (3.5)$$

Highlighting the water quality result of the three (3) variables in Equation (3.2) in Table 3.2 The various variable and constants in equation 3.2 were further transformed to determine Table 3.3, which are variables in Equations 3.3, 3.4 and 3.5

Table 3.2: Variables for the multiple regression model from the Nworie water analysis

Locations	1	2	3
DO (mg/l)	6.5	5.8	4.0
Temp ^{0}C	24	25	25
TDS(mg/l)	40	48	73

Table 3.3: Transformed data for evaluating the Equation (3.1)

Y = Log DO	x_1 = Log Temp.	x_2 = Log TDS	x_1^2	x_2^2	x_1y	x_2y	x_1x_2
0.8129	1.3802	1.6021	1.904952	2.566724	1.121965	1.302347	2.211218
0.7634	1.3979	1.6812	1.954124	2.826433	1.067157	1.283428	2.350149
0.6021	1.3979	1.8633	1.954124	3.471887	0.841676	1.121893	2.604707
ΣY=2.1784	Σx_1=4.176	Σx_2=5.1466	$\Sigma\ x_1^2 = 5.8132$	$\Sigma\ x_2^2 = 8.8651$	$\Sigma\ x_1y =$ 3.0308	$\Sigma\ x_2y =$ 3.707668	$\Sigma\ x_1x_2 =$ 7.16607

The equation 3.3, 3.4, and 3.5 gave:

$$2.1784 = 3a_0 + 4.176a_1 + 5.1466a_2 \quad (3.6)$$

$$3.0308 = 4.176a_0 + 5.8132a_1 + 7.1661a_2 \quad (3.7)$$

$$3.7077 = 5.1466a_0 + 7.1661a_1 + 8.8651a_2 \quad (3.8)$$

The matrix equation gave:

$$\begin{bmatrix} 3 & 4.176 & 5.1466 \\ 4.176 & 5.8132 & 7.1661 \\ 5.1466 & 7.1661 & 8.8651 \end{bmatrix} \begin{Bmatrix} a_0 \\ a_1 \\ a_2 \end{Bmatrix} = \begin{Bmatrix} 2.1784 \\ 3.0308 \\ 3.7077 \end{Bmatrix}$$

Applying inverse matrix to the matrix above to find a_0,a_1, and a_2 respectively

$$\begin{Bmatrix} a_0 \\ a_1 \\ a_2 \end{Bmatrix} = \begin{bmatrix} 3 & 4.176 & 5.1466 \\ 4.176 & 5.8132 & 7.1661 \\ 5.1466 & 7.1661 & 8.8651 \end{bmatrix}^{-1} * \begin{Bmatrix} 2.1784 \\ 3.0308 \\ 3.7077 \end{Bmatrix}$$

$$\therefore \begin{Bmatrix} a_0 \\ a_1 \\ a_2 \end{Bmatrix} = \begin{Bmatrix} 0.2359 \\ 1.4664 \\ -0.9041 \end{Bmatrix}$$

Therefore, a_0=0.2359, a_1=1.4664 and a_2=-0.9041.

Taking the antilog to base 10 to convert the linearized dissolved oxygen equation back to the original form (i.e., non-linear form) demand that:

But, C=$10^{a_0} = 10^{0.2359} = 1.7214$

The required dissolved oxygen equation becomes:

$$DO = 1.7214 Temp.^{1.4664}\ TDS^{-0.9041} \quad (3.8)$$

The estimate of the dissolved oxygen, DO was calculated by substituting the values shown in Table 3.2into Equation 3.8.

Location 1:

$$DO = 1.7214(24).^{1.4664}\ (40)^{-0.9041} \quad (3.9)$$

$$DO = 6.477\ mg/l$$

Location 2:

$$DO = 1.7214(25).^{1.4664}\ (48)^{-0.9041} \quad (3.10)$$

$$DO = 5.832\ mg/l$$

Location 3:

$$DO = 1.7214(25).^{1.4664}\ (73)^{-0.9041} \quad (3.11)$$

$$DO = 3.992 \frac{mg}{l}$$

Relationship between Estimated DO and Observed DO is shown in Table 3.5.This is also illustrated using the coefficient of rank correlation.

Table 3.4: Relationship between Estimated DO and Observed DO

Locations	**1**	**2**	**3**
DO (mg/l)observed	6.500	5.800	4.000
DO (mg/l) estimated	6.477	5.832	3.992
Difference	0.023	- 0.032	0.008
D^2	0.000529	0.001024	0.000064

The coefficient of rank correlation or spearman's formula for rank correlation is given by:

$$r_{rank} = 1 - \frac{6\Sigma D^2}{n(n^2-1)} \quad (3.12)$$

$$r_{rank} = 1 - \frac{6(1.6X10^{-3})}{3(3^2-1)} \quad (3.13)$$

$$r_{rank} = 0.9996$$

The rank correlation of 0.9996 indicates that there is a marked relationship between achievements in observed DO and estimated DO from the model.

3.2 Discussion

Table 3.2 shows the variables for the multiple regression model from the three sample locations which were derived from the physicochemical analysis of the three water samples (Table 3.1). The variables were DO, Temperature and TDS. These variables were further analyzed, transformed and evaluated using Equation (3.1)(Table 3.3) to generate Equation (3.8). This equation becomes the empirical model i.e.,the required dissolved oxygen equation. The estimates of the dissolved oxygen in the three locations were, calculated by substituting the values shown in Table 3.2. The relationship between the estimated and observed Dissolved Oxygen is shown in Table 3.4. The relationship was further correlated with a correlation coefficient'r' of 0.9996. This value indicated that there is a marked relationship between achievements in observed DO and estimated DO from the model. Also, the highly positive correlated result of the observed value to the laboratory dissolved oxygen implied that the model provides a good approximate solution in determining physicochemical parameters in water(Udeorji et al., 2018). Hence, the multiple regression model is strongly accepted for use in determining the relationship of DO, Temperature and total dissolved solidsof physicochemical parameters of water.

4. Conclusion

Having met the specific objective of this work. It has been shown that multiple regression models are effective in predicting the relationship of some physicochemical parameters of a river. Further observation from the result also showed that temperature and total dissolved solids (TDS) of a river affects the values of dissolved oxygen. This implies that an increase in temperature and dissolved substances affects the health of a river. Therefore, this research will benefit environmental engineers and others whose interest is on monitoring the environment and natural changes occurring in a watershed. Comparing the result of the physicochemical parameters of the river with the WHO set standard, it was observed that few parameters exceeded the standard limits set by the World Health Organization, WHO like conductivity, TSS, Turbidity, DO and calcium. This result of the relationship between estimated DO and laboratory DO agrees with other researchers that the Nworie River was polluted by organic wastes (Nnaji&Duru, 2006;Umunnakwe*et al.,* 2011).

Recommendations

The following recommendations were made after the conclusion of the study:

(i) To prevent contamination of our river, much consideration should be paid to the environment.
(ii) Industrial, municipal and agricultural effluents discharged into our rivers and streams should be treated in order to maintain the WHO set limit for rivers and other water bodies to ensure the sustainability of aquatic life.

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