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Evaluation of the Pollution Status of Nwondugba Stream in Obio/Akpor in Rivers State

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Abstract
This study was done on Nwondugba stream in Obio/Akpor, Rivers State. The aim was to determine the assimilative capacity and longitudinal dispersion of Nwondugba stream. The study acquired data on hydraulic and physico-chemical parameters of the stream and longitudinal dispersion coefficient. The results of physico-chemical parameter obtained from laboratory analysis was compared with standards and used in evaluating the effect of abattoir and municipal wastewater on the stream. The hydraulic and physico-chemical data of both dry and wet seasons of the stream were subjected to student t-test to determine significant difference of the two seasons. The test result showed significant variations in depth, velocity, temperature, TSS, DO and TDS and no significant difference was established in discharge, pH, COD and BOD. The mean depth, velocity, discharge, DO, pH, temperatures, BOD, COD, TDS, and TSS for rainy season were 0.98m,0.53m/s, 5m^3/s ,3.9mg/l, 6.23, 22.7^{o}C, 15.08mg/l,37.71mg/l,106mg/l and 64.2mg/l, respectively. While their mean values during the dry season were 0.38m,0.16m/s,0.47m^3/s,4.8mg/l,6.33,23.6^{o}C,14.05mg/l,35.06mg/l,33.6mg/l, and 19.3mg/l, respectively. Temperature and TDS were within FMEnv. (35^{o}C) and WHO (1000mg/l) standards for all sample stations. The mean self-purification factors were 0.72 for rainy season and 0.61 for dry season. These values indicated that the stream is a small pond and sluggish in nature. It is recommended that the usageof Nwondugba stream water for domestic purposes without proper treatment should be discouraged, and stakeholders and relevant authorities shouldsetup waste control measure and monitoring programme for the stream.

***Keywords:**Assimilative capacity, Physicochemical, Dispersion, Self-purification*
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1. Introduction

Surface waters are associated with many problems which are caused by pollutant release into many rivers, especially those crossing inhabited areas (Elisabeta, 2010). Rivers and streams pollution is a serious global challenge in modern times, and this threatens the health and well-being of humans, plants and animals (Zhang and Boufadel, 2010).It is now obvious not to think that one could drink water from any water course because the increase in the level of pollutant entering water bodies through municipal and commercial activities is alarming (Heron, 2015).Surface water is very useful to man in multiples ways, hence, stream flow rate, velocity of flow, auto purification capacity of water bodies and solute dispersion are of interest to the water resources and public health engineers. From the framework of this study, it is established that water pollution has been extensively investigated by prominent researchers (Fischer et al., 1979; Agunwamba et al., 2006; Longe and Omole,2008; Chiejine et al., 2015; Ahoet al., 2016; Yuqi, 2017; Nwaogazie et al., 2017). Also, field measurement is required to ascertain suitable and reliable data for determining water pollution profiling. There is also need to consider self-purification processes in stream to truly ascertain stream pollution. According to Omeje (2005), high demand for streams evaluation is a significant force of self-purification, such as deoxygenation and re-aeration properties which becomes increasingly necessary potential indicator in pollution build up in streams, lakes, and estuaries. Natural biological purification process using physicochemical analysis helps to determine level of pollution in stream (Longe and Omole, 2008; Florescu et al., 2010; Survil et al., 2017).

The protection of aquatic life is very important and there is need for effective determination of stream capacity to assimilate wastes. Dissolved oxygen (DO) and the biochemical oxygen demand (BOD) are two important parameters in determining pollution profile and self-purification of streams. The holding capacity of dissolved oxygen that can be held in water depends mainly on the water temperature (Agunwamba et al., 2006; Longe and Omole, 2008; Samuels et al., 2013). The estimation of dissolved oxygen concentration relation to its saturation value and the rate of oxygen usage in stream is measured as its BOD. This proves to be a good measure for identifying pollution state of a water body (Jaksebogait and Barvidiene, 2015). Also, dissolved oxygen measured in stream has been used as standard to predict aerobic degradation and self-purification capacity of water bodies (Omole et al., 2012; Chiejine et al., 2015; Marozait and Šaulys, 2015; Han, 2015). The current study is to evaluate the pollution state of Nwondugba stream using dissolved oxygen model.

2. Materials and methods

2.1 Study area

This research was carried out in Nwondugba stream in Eliozu community in Obio/Akpor local government area, Rivers State. The river flows from Rukpokwu down to Eliozu where it meets a tributary that flows to Airforce (Rumuomasi) crossing East-West Road. The study area enjoys humid hot downpour climate due to its latitudinal position. It is located between latitude 4°45'N and 4°60'N and longitude 6°50'E and 8°00'E in the Niger Delta of Nigeria. Fig. 1 indicates the stream of study.

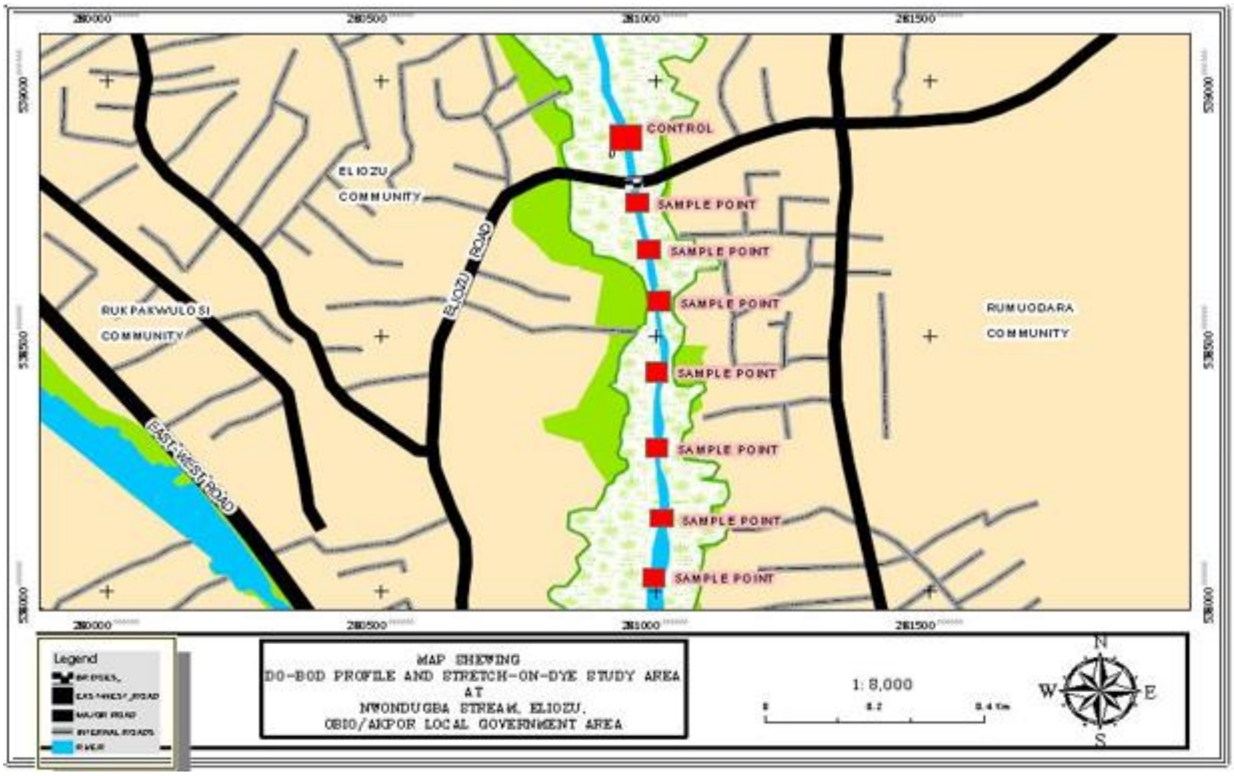

Fig. 1: Nwandugba river showing sample collection points

2.3 Data collection and analysis

The field sampling and data collection were carried out along the river channels at best points. The primary data were those obtained from field work, through personal observations, measurements of stream hydraulic parameters and sample collection along sample points with simple instrument such as floater, thermometer, stopwatch, measurement tape, and sterilized bottles. Methods of data analysis included laboratory and statistical analyses. Standard laboratory method was used to measure the following parameters: Dissolved oxygen (DO), Biochemical oxygen demand BOD), Chemical oxygen demand (COD), Total suspended solid (TSS), Total dissolved solid (TDS), coli form and pH. While statistical analysis was carried out with the aid of Microsoft excel software, and obtained results were plotted graphically to show comparison between the measured parameters. Seasonal variation analysis was performed, using student t-test, on the hydraulic parameters and the physicochemical parameters.

Existing DO model was used to predict stream pollution position Longe and Omole,2008; Chiejine et al.,2015; Omole et al.,2012).

$$DOt = \frac{KdLo}{K2-K1}(e^{-k1t}-e^{-k2t})+Dae^{-k2t} \quad (1)$$

where DOt is the DO deficit in mg/l after time t, Lo is the Ultimate first stage BOD of mix at the point of discharge in mg/l, Da is the Initial dissolved oxygen deficit of the mix at the mixing point in mg/l, $K_1$is the De-oxygenation coefficient (day-1), K_2 is the Re-oxygenation coefficient (day-1), and t is the Time of travel of waste discharge downstream (day).

The time required to reach the critical point(t_c**)** was obtained by differentiating Equation (2) with respect to t and equating to zero:

$$tc = \frac{1}{k2-k1}\ln\left[\frac{k2}{k1}\left(1 - Da\frac{k2-k1}{k1Lo}\right)\right] \quad (2)$$

where t_c is the critical time, and k_2, k_1, Da and Lo are as defined above.

The critical dissolved oxygen deficit (DOc) was calculated using Equation (3) obtained by substituting critical time t_c in the general DO deficit equation.

$$DOc = \frac{k1}{k2}Loe^{-k1tc} \quad (3)$$

The critical deficit $D_c = DO_s - DO_c$ (4)

where DOs is dissolved oxygen at saturation point. The location of the critical distance Xc which is very important because it gives clue of pollution within such reach was determined using Equation (5).

$$X_c = v \times t_c \quad (5)$$

where Xc is the critical distance (m) and v is the velocity of flow (m/d).

Self-purification was determined using Equation (6).

$$F = \frac{k_1}{k_2} \quad (6)$$

3. Results

Tables 1 and 2 show the results of hydraulic parameters of Nwondugba stream in the rainy and dry seasons respectively. Tables 3 and 4 show the results of the physicochemical parameters of the stream location with standards in the rainy and dry season respectively. Tables 5 and 6 present the self-purification factor of the stream in rainy and dry season, respectively. Figures 2 and 3 present the relationship between the measured and predicted DO of the stream in rainy and dry season, respectively.

Table 1: Hydraulic parameter of the stream for rainy season

Location	Width(m)	Depth(m)	Area(m^2)	Velocity(m/s)	Discharge(m^3/s)
Control	11.23	0.96	10.78	0.378	4.06
Station 1	9.33	1.08	10.08	0.704	7.09
Station 2	10.67	0.87	9.28	0.617	5.73
Station 3	10.42	1.02	9.59	0.526	5.04
Station 4	9.21	0.88	8.10	0.508	4.12
Station 5	9.25	1.04	9.62	0.432	4.16

Table 2: Hydraulic parameter of the stream for dry season

Location	Width(m)	Depth(m)	Area(m^2)	Velocity(m/s)	Discharge(m^3/s)
Control	9.06	0.51	4.60	0.124	0.57
Station 1	7.45	0.54	3.99	0.225	0.90
Station 2	8.64	0.32	2.77	0.163	0.45
Station 3	7.88	0.35	2.74	0.157	0.43
Station 4	6.36	0.25	1.57	0.142	0.22
Station 5	7.00	0.30	2.13	0.119	0.25

Table 3: Physicochemical parameters of stream for rainy season

Parameters	Control	Station 1	Station 2	Station 3	Station 4	Station 5	FMEnv	WHO
pH	6.8	5.9	6.1	5.8	6.5	6.3	6.5-8.5	6.5-8.5
DO (mg/l)	3.1	4.2	3.2	3.8	4.1	5.5	-	5
BOD_5 (mg/l)	10.6	14.1	23	20.7	12.8	9.3	10	-
COD (mg/l)	26.5	35.25	57.5	51.75	32	23.25	40	-
TDS	60	144	168	103	89	72	-	1000
TSS	51	96	102	58	41	37	30	-
Temp.	23	22.8	23	22.6	22.6	22.5	35	-

Table 4: Physicochemical parameters of stream for dry season

Parameters	Control	Station 1	Station 2	Station 3	Station 4	Station 5	FMEnv	WHO
pH	6.48	5.79	6.3	6.4	6.8	6.2	6.5-8.5	6.5-8.5
DO (mg/l)	4	4.6	4.3	4.8	5.4	6.4	-	5
BOD_5 (mg/l)	9.5	13.2	18.9	13.9	14.2	14.6	10	-
COD (mg/l)	23.75	33	47.23	34.75	35.5	36.15	40	-
TDS	16	24	54	43	36	29	-	1000
TSS	8	13	38	24	18	15	30	-
Temp.	24	23.7	23.9	23.5	23.5	23	35	-

Table 5: Self-purification factor of stream in rainy season

Stations	Distance (m)	Rainy season K_2(mg/l)	Rainy season K_1(mg/l)	$F=k_2/k_1$
1	50	0.201	0.504	0.40
2	100	0.018	0.014	1.30
3	150	0.116	0.120	1.0
4	200	0.179	0.600	0.30
5	250	0.542	0.920	0.60
			Average	0.72

Table 6: Self-purification factor of stream in dry season

Stations	Distance (m)	Dry season K_2(mg/l)	Dry season K_1(mg/l)	$F=k_2/k_1$
1	50	0.095	0.504	0.19
2	100	0.023	0.145	0.16
3	150	0.147	0.452	0.33
4	200	0.318	0.431	0.74
5	250	0.649	0.403	1.61
			Average	0.61

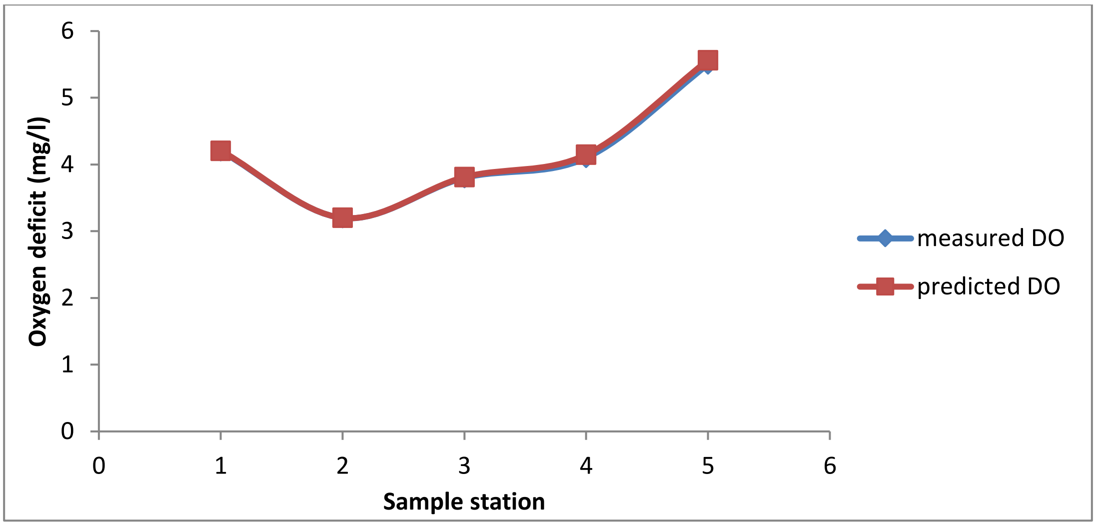

Fig. 2: Measured and predicted DO for rainy season

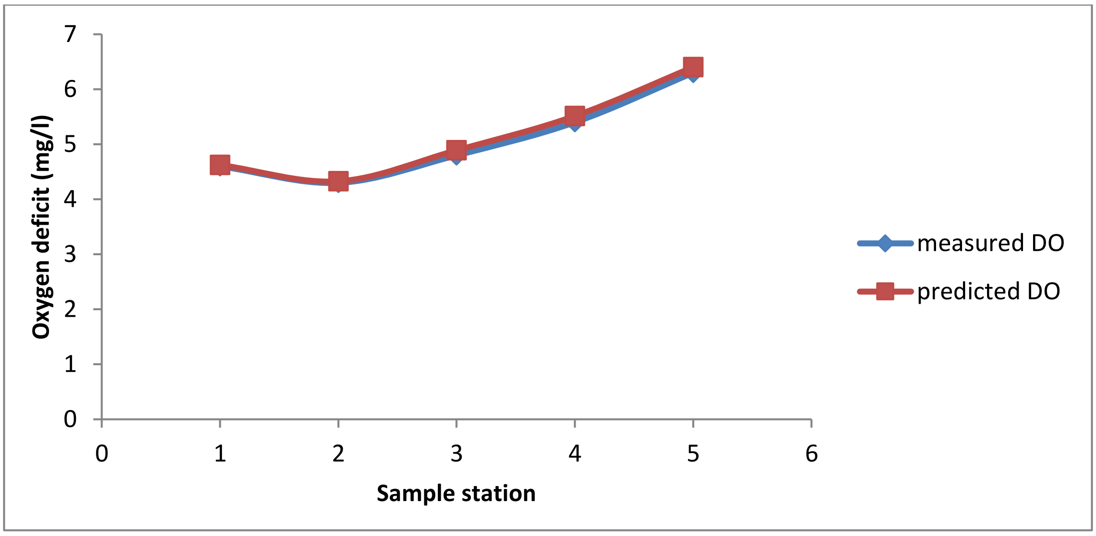

Fig. 3: Measured and predicted DO for dry season

4. Discussion

The DO concentrations of the water sample ranged from 3.1mg/l to 5.5mg/l for rainy season and 4mg/l to 6.4 mg/l for dry season. The DO concentrations of most sample stations were not within the WHO standard(5mg/l) for both seasons. Only sample station 5 of both rainy and dry season, and stations 4 and 5 of dry season were within WHO (5mg/l). Sample station 4 in the rainy season showed signs of recovery in the DO content of the river as one moves downstream. DO values increases gradually until it reaches a value of 5.5mg/l in station 5 in the rainy season. The reason for the DO increase as one moves downstream could be attributed to lower temperature at that period of the year which enhanced the capacity of the water to hold more oxygen thus increasing the amount of oxygen of the river water. However, it was found that the DO of the stream in the dry season had a low trend from sample stations 2, 3 and 4. The low trend of the DO of the stream indicates low mixing capacity as a result of increase in temperature and low rainfall. DO recovery in dry season started building up from sample station 4 and reached a value of 6.4 mg/l at station 5. It was also observed during dry season the stream experience low volume of the effluent discharge from the point source around the abattoir and there was very low patronage to the slaughterhouse. This means less nutrient for the organic microbes to utilized and further means less oxygen was consumed in that process. Since the oxygen consumed is less than the oxygen added via re-aeration, this increased the DO content of the water at the dry season, resulting in a significant difference in the DO of both seasons ($p<0.05$).

The range of BOD values were between 9.3mg/l and 23.9mg/l for the rainy season and between 9.5 mg/l and 18.9 mg/l for the dry season. The mean BOD concentrations of 15.08mg/l and 14.05mg/l in the rainy and dry season were higher than the FMEnv standard (10mg/l). BODs were higher during the rainy season than the dry season for the measured segments of the river. This suggest that more effluents were release from runoff, as a result of high demand from the slaughterhouse and high municipal discharge into the stream during rainfall. This result agrees with the findings of other studies (Eneji et al., 2013). There is no significant difference in the BOD of both seasons ($p > 0.05$).

COD values of the stream ranged from 23.25mg/l to 59.75mg/l in the rainy season and 23.75 mg/l to 47.23mg/l in the dry season. The COD concentration for sample station 2 (57.5mg/l) and station 3 (51.75mg/l) in the rainy season and sample station 2 (47.23mg/l) in the dry season were higher than the FMEnv standard (40mg/l). The CODs were higher in the rainy season than in the dry season. This could still be attributed to increase in organic and inorganic waste load noted during rainy season. There were variations of COD values across the sampling points with however no significant seasonal variation ($P>0.05$).

The ultimate BOD ranged from13.58mg/l to 34.89mg/l with an average value of 23.33mg/l for rainy season while dry season ranged from19.27mg/l to 27.59mg/l with an average value of 21.84mg/l. The ultimate BOD has a high value in sample station 2in both rainy season (34.89mg/l) and dry season(27.59mg/l). This also depicts that station 2 experienced low DO value thereby leading to pollution of the stream segment.

The re-aeration rate constant ranged from $0.018d^{-1}$ to $0.542d^{-1}$ with an average value of $0.211d^{-1}$ for rainy season while dry season ranged from $0.023d^{-1}$ to $0.649d^{-1}$ with an average of $0.246d^{-1}$. The results show that less effluent was released into the stream in dry season thereby favouring re-aeration rate value in dry season than rainy season.

The de-oxygenation rate constant ranged from $0.014d^{-1}$ to $0.920d^{-1}$ with average value of $0.432d^{-1}$for rainy season while that of dry season ranged from $0.145d^{-1}$ to $0.504d^{-1}$ with an average value of $0.387d^{-1}$. The average values of K_1 for both rainy and dry season show that the effluent discharged into the stream was a strong wastewater (Fair et al., 1971). The averaged self-purification factor was 0.72 for rainy season and 0.61 for dry season. The ratio of average values of self-purification (F) in the rainy season and dry season was less than unity which means that de-oxygenation rate was higher than re-aeration across the stretch of the river studied.

The DO profile of the stream was estimated using the Streeter-Phelps (1925) model. The measured DO level shows increase at sample station 1 (50m) and decrease downstream at sample station 2 (effluent discharge point) 100m along the stream. After this point the DO level begins to increase gradually as a result of self-purification capacity of the stream. This trend was the same in both rainy and dry season. The results of the analysis revealed that the critical time (tc) occurred at a distance of 100m downstream with time 0.0071 day at DO of 3.2mg/l for rainy season and 0.0018 day at DO of 4.2mg/l at the same distance of 100m in the dry season. In all, the predicted DO model was found to be a relatively close match of the measured DO.

4. Conclusions

This study revealed that activities going on at the bank of Nwondugba stream such as the discharge of abattoir wastes, human sewage, animal wastes as well as effluent from fishpond have been identified as major sources of pollution in the stream. The results of the study indicated that the Nwondugba stream water is unsafe for domestic purposes without some forms of physical treatments. The minimum DO values for the stream segment was found to be 3.2mg/l in rainy season and 4.3mg/l in dry season which are below the FMEnv. and WHO standards of 5 to 8mg/l, indicating that the aquatic life within the segment of the stream could be adversely affected. The self-purification factor value for rainy and dry seasons (0.72 and 0.61) were less than unity, implying that the stream is slightly polluted. The t-test analysis showed significant variations in temperature, TSS, DO, TDS, depth, discharge, and velocity between the seasons, and no significant difference in the COD, BOD, and pH. It is recommended that the usage of Nwondugba stream water for domestic purposes without proper treatment may result to public health problem and therefore should be discouraged. Also, waste disposal into the stream stretch should be monitored and controlled to avoid stream water quality deterioration.

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