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A Study of Self-purification Capacity of Anyim Stream

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Abstract

This paper studied the self-purification capacity of Anyim stream to identify the location where pollution load is comparably less for water abstraction and economical treatment and distribution to consumers. Standard methods were used to determine the water quality parameters along the stream reach. Results show that temperature remained constant at 26.60℃, turbidity reduced from 145.4 NTU to 85.0 NTU, average color along the stream were 198.33 PCU, 192.33 PCU, 121.33 PCU and 135.67 PCU, average dissolved oxygen trend were 6.0 mg/l, 8.0 mg/l, 4.0 mg/l and 7.0 mg/l. BOD trend presented 15.0 mg/l, 10.0 mg/l, 30.0 mg/l and 20.0 mg/l. Maximum oxygen deficit of 9.17 mg/l occurred in 4.42 days while maximum oxygen recovery of 31.46 mg/l happened in 21.68 days. Complete self-purification will take place at a distance of 114.57 km downstream of the influent station of Anyim stream. The trend show that water in Anyim stream experienced self-purification from Okosi through Ahaba to Okporo-akanu and increased to Amaokwe because of effluent from confluence station of Anyim and Etu streams. It is recommended that water should be sourced downstream of Okporo-akanu and 114.57 km downstream of Anyim stream for treatment and distribution to consumers since these sources would require less elaborate treatment methods and hence would be cheaper and more economical to manage.

Keywords: A Study, Self-purification, Capacity, Anyim, Stream

1.0 INTRODUCTION

Water is one of the most important resources in the environment that supports life, it also influences the climate and inhibits civilization[1]. Qualitatively and quantitatively, water resources management requires frequent monitoring for adequate valuation of extent of pollution for effective conservation and frugal utilization of water bodies. An important tool used for solution of problems related to surface water pollution is modeling of variations that occur in lake water bodies and corresponding water quality variations [2]. One of the most popular models for the determination of BOD and dissolved oxygen profiles along a river reach is based on the 1925 classical studies of Streeter and Phelps [3, 4]. In the analysis of river self-purification considering biogenic substances, self-purification capacity can be computed from the model [5].

$$\alpha = \ln(C_0 C_L^{-1})L^{-1} \quad (1)$$

where: C_0- concentration of chemical material at the beginning of the relevant river stretch (mgL^{-1}); C_L – concentration of chemical material at the end of the relevant river stretch (mgL^{-1}); L – length of river stretch (km).

It is known that in order to support basic needs,anthropogenic activities arising from land utilization around river stretches may give rise to some environmental problems such as water body contamination from household wastes, industrial and agricultural wastes [6]. Self-purification is the capacity of a river to purify its water from any contaminant provided the pollutant still fall below established quality standard. Self-purification takes place as a result of oxidation of organic substances by aerobic microorganisms; due to the presence of decomposed organic matter in receiving streams and subsequent reactions such as physical, chemical and biological that filter any contaminants and allows a river to recover its natural condition over a given distance [7, 8].

However, dissolved oxygen (DO) concentrations in a water body is an important factor in determination of overall effect of organic substances [9, 10]. The rate of dissolved oxygen consumed by microorganisms which depends on the type of organic substances is usually represented as k_1, a value which decreases as the organic substances becomes harder to decompose and vice versa. The reaeration coefficient k_2 is described as the addition rate of dissolved oxygen in the river. However, variations

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in oxygen content of polluted river can be studied with the aid of dissolved oxygen sag curve [11]. Biological oxygen demand (BOD) is a parameter used to measure the quantity of dissolved oxygen needed by aerobic microorganisms to decompose organic matter [12].

Anyim Stream, though heavily polluted due to effluent discharge from many tributaries, is a source of water supply to many villages around it. Government is faced with the challenge of extent of treatment to be given to this water after abstraction before distribution to consumers. Therefore this study analyzed the self-purification capacity of this stream to enable government make timely decision on the most frugal way of achieving this objective, and also to know at what locations where pollution load is less for water abstraction that would require less elaborate treatment, hence cheaper and more economical to manage.

2.0 MATERIALS AND METHOD

2.1 The Study Area

Anyim Stream is a perennial Stream. It has its source at Ozuitem and flows across Bende Road Bridge at Onu-Inyang, then flows through Okporoenyi, Nkalunta, Obuoro, Itunta in Ikwuano LGA and moved through Ntalakwu Ancient Kingdom, flows through Okosi, Ahaba, Okporo-Akanu and Amaokwe, and then discharges into a higher order Itu stream in Akwa Ibom State.

Anyim Stream is a source of water supply to many villages around it. Water from the stream is relatively clear, though it is polluted at some points. During dry seasons and periods of water scarcity, Anyim stream serves the water need of the people around it.

Four sampling points were selected along the Stream for the analysis. The sampling points are; Okosi sampling points, Ahaba sampling points, Okporo-Akanu sampling points and Amaokwe sampling points. And these sampling points are where other streams meet the Anyim stream. The map of study area is shown in figure 1 below

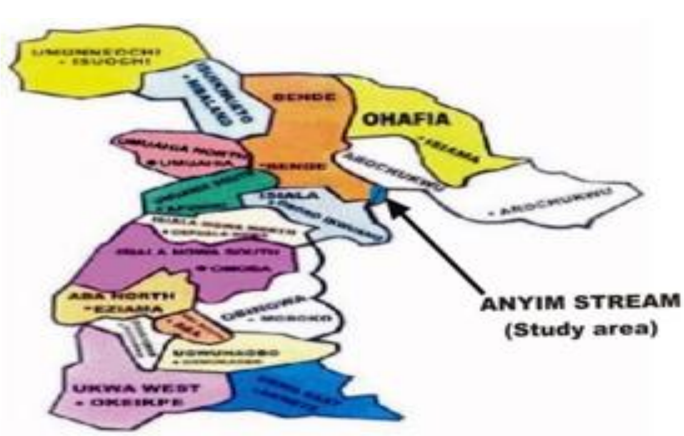

Fig. 1: Map of Study Area

2.2 Samples and Sampling Techniques

Water samples were collected from four stations, A, B, C, and D along the stream reach. Station A at Okosi is the confluence station of Anyim and Agalama streams, while station B at Ahaba is the confluence station of Anyim and Onukpu streams. Station C at Okporo-akanu is the confluence station of Anyim and Etu streams, while station D at Amaokwe is the confluence station of Anyim and Edonyi streams. The distances separating the four stations is 9.0 km each, and three samples were collected between two stations spaced at 3.0 km intervals. Influent station being the first sampling point which served as control was considered 1.0 km away from the confluence station A which situate at Okosi. The container for water samples was a 6-liter capacity plastic can which was thoroughly rinsed with the water from the stream. Water samples were stored in a refrigerator maintained at 4℃ in order to deactivate microbial activities which is time-dependent before the start of experiment.

3.0 EXPERIMENTAL PROCEDURE

Standard method were used in determination of water quality parameters. The closed bottle test fully described in [13] was used for determination of biochemical oxygen demand (BOD). Turbidity were determined using the turbidity meter (Model 0.01-1100 Ntu PVC turbidity meter with infrared light source), temperatures were measured with the aid of a LUMISCOPE® digital thermometer (Model L2214), colors were measured with Apogee® spectroradiometers (Model PS-300), dissolved oxygen concentrations were determined with INSTRUMART® dissolved oxygen sensor (Model GF Signet 2610), average flow rates of water were measured with flow meter, hand held global positioning system (GPS) (Garmin® eTrex Legend) was used to obtain the coordinates of the stations. The data obtained from these measurements were used for computation of essential parameters such as deoxygenation and reaeration levels using the Streeter-Phelps model [14] thus;

$$D_t = \frac{K_1 L_0}{K_2 - K_1}\left[e^{-K_1 t} - e^{-K_2 t}\right] + D_0 e^{-K_2 t} \quad (2)$$

Where;

$K_1 = K_{1_{(20)}}(1.047)^{T-20}$

$K_2 = K_{2_{(20)}}(1.016)^{T-20}$

D_t = value of oxygen deficit in the pollutant at time t (mg/l)

L = concentration of BOD (mg/l)

t = time of travel between two stations

$T =$ values of K_1 and K_2 at temperature of 20℃

Equation (2) is the oxygen sag curve, in which stream self-purification ratio, $f = K_2/K_1$ so that Equation (2) is modified thus;

$$D = \frac{L_A}{f-1}\left[1 - e^{[-(f-1)K_1 t]}\left[1 - (f-1)\frac{D_0}{L_A}\right]\right]e^{-K_1 t} \quad (3)$$

The oxygen sag curve, Equation (3) has two characteristic points, the critical point being a point of maximum deficit $(D_{c,}\ t_c)$; and a point of inflexion being the point of maximum recovery $(D_{i,}\ t_i)$, represented by Equations (4) to (7)

$$D_c = \frac{L_A}{f\{f[1-(f-1)(D_0/L_A)]\}^{1/(f-1)}} \quad (4)$$

$$t_c = \frac{1}{(f-1)K_1}\ln f\left[1 - (f-1)\frac{D_0}{L_A}\right] \quad (5)$$

$$D_i = \frac{(f+1)L_A}{f^2\{f^2[1-(f-1)(D_0/L_A)]\}^{1/(f-1)}} \quad (6)$$

$$t_i = \frac{1}{K_1(f-1)}\ln f^2\left[1 - (f-1)\frac{D_0}{L_A}\right] \quad (7)$$

BOD of the mixture of sewage and stream water is given by the expression;

$$L_m = \frac{L_e Q_1 + L Q_1}{Q_1 + Q_2} \quad (8)$$

Where L_e and L are the BOD of the effluent in the stream and at the discharge point, Q_1 and Q_2 are the flow rates of the effluent in the stream and at the discharge point respectively.

4.0 RESULTS AND DISCUSSION

Table 1 show the water quality parameters at confluence stations A, and at stations B and C before the next confluence station along the stream reach. The confluence stations occur at Okosi, Ahaba, Okporo-akanu and Amaokwe respectively. The distances separating the stations are 3.0 km making a total of 9.0 km betweenstation A (Okosi) and station C within the range of Okosi confluence station. These separating distances also apply to intervals between Ahaba, Okporo-akanu and Amaokwe.

Table 1: Water quality parameters at Okosi, Ahaba, Okporo-akanu and Amaokwe confluence stations

Water quality parameters	**FMENV standard**	**Okosi (N: 5.5169817, E: 7.6664450)**			**Ahaba (N: 5.5238876, E: 7.6654989)**			**Okporo-akanu (N: 5.1540271, E: 7.6729543**			**Amaokwe (N: 5.4682355, E: 7.5661968**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Temp. (℃)		26.70	26.60	26.70	26.60	26.60	26.60	26.60	26.60	26.70	26.70	26.50	26.60
Av. Temp. (℃)	20-30	26.70			26.70			26.70			26.70		
Turbidity (NTU)		73.0	103.5	93.1	115.0	208.0	113.3	114.7	121.9	62.0	95.2	90.5	72.0
Av. Turbidity (NTU)	5.0	89.9			145.4			99.5			85.0		
Color (PCU)		70	300	205	197	180	250	80	100	184	157	114	142
Av. Color (PCU)	15.00	198.33			192.33			121.33			135.67		
DO (mg/l)		5.9	6.0	6.2	8.0	8.1	8.5	4.0	4.4	4.6	6.9	7.1	7.4
Av. DO (mg/l)	> 4	6.0			8.0			4.0			7.0		
BOD (mg/l)		15.3	14.9	14.6	10.2	9.8	9.6	30.3	29.8	28.0	20.1	19.5	19.0

Water quality parameters	**FMENV standard**	**Okosi (N: 5.5169817, E: 7.6664450)**			**Ahaba (N: 5.5238876, E: 7.6654989)**			**Okporo-akanu (N: 5.1540271, E: 7.6729543**			**Amaokwe (N: 5.4682355, E: 7.5661968**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Av. BOD (mg/l)	NS	15.0			10.0			30.0			20.0		

Table 1 present the water quality parameters along Anyim stream. Temperature remained constant at every point along the stream which indicates that variation in water quality does not affect temperature. Turbidity response concentrations increased to maxima values at stations B, 9 km from all the confluence stations, in line with behavior of dispersion of tracers in streams [15]. However, average values of turbidity increased from 89.9 NTU to a maximum of 145.4 NTU, then to a minimum value of 85.0 NTU due to stream self-purification. Similar trend was observed in stream color because color increased to a maximum value of 300 PCU at station B and decreased to 205 NTU at station C due to influence of effluent at Okosi. There was continuous increase in color along Okporo-akanu to a maximum value of 184 PCU. Amaokwe presented a decrease from the confluence point to station B, and thereafter, an increase in value at station C, the borderline between Amaokwe and downstream.

These anomalous behaviors from the findings is evident from the various forces helping self-purification capacity in streams, such as physical forces which include; dilution, dispersion, and sunlight. Chemical forces aided by biological forces like oxidation and reduction. Also, self-purification capacity of a river or a stream is a function of such factors like temperature, river or stream hydraulics such as velocity and its surface expanse, reaeration rate, amount and type of organic matter, available initial dissolved oxygen, and types of microorganism present. Self-purification depend on stream depth, light energy and amount of algae [16, 17].

The results show that apart from the factors governing stream self-purification with respect to water quality parameters in stream pollution, stream hydraulics not considered by many researchers may have played important role from the findings in this study. However, the self-purification of natural water systems is a complex process and often involves physical, chemical and biological processes working simultaneously

Figure 2 is a plot of variation of water quality parameters with distance along Anyim stream. This plot show that as the BOD of stream water increases, the DO continues to decrease and vice versa.

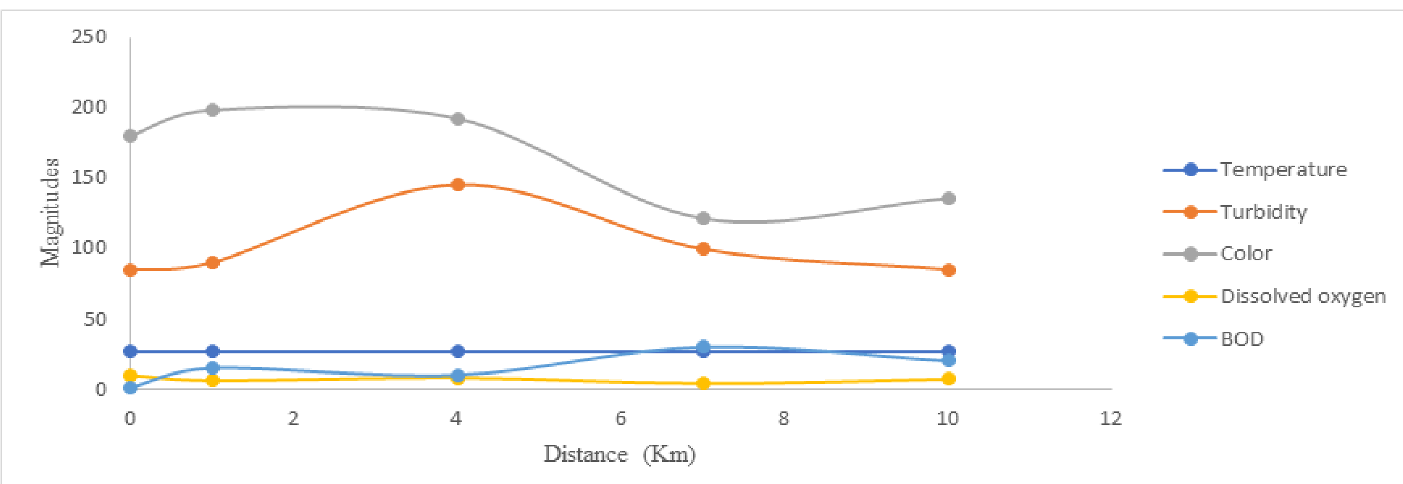

Fig. 2: Plots of variation of water quality parameters with distance along Anyim stream

Table 2 present the variation of water quality parameters along Anyim stream reach due to effluent discharges into the water body. BOD mixture of the stream increased continually from 1.000 mg/l at the influent, Anyim to 5.000 mg/l at Anyim/Okosi confluence station, and then to 6.142 mg/l, 11.672 mg/l and 14.740 mg/l at Okosi/Ahaba, Ahaba/Okporo-akanu and Okporo-akanu/Amaokwe confluences respectively, evidencing the influence of contaminated effluent discharges along the stream reach. However, DO deficit increased from 1.090 mg/l to a maximum value of 7.337 mg/l at Okosi/Ahaba Confluence and decreased to a minimum value of 0.78

mg/l at Okporo-akanu/Amaokwe confluence. Therefore, it is encouraged to abstract water from a distance downstream of this point for treatment and supply to consumers in this community. Logically, low DO deficit implies high DO content and low BOD as organic matter content in stream has decreased appreciably.

Looking at the critical points, maximum oxygen deficit of 9.17 mg/l occurred in 4.42 days while maximum oxygen recovery of 31.46 mg/l happened in 21.68 days. Though it is recommended that water should be sourced from a distance downstream of Okporo-akanu/Amaokwe confluence for treatment and supply to consumers, the best location to source for water should be 114.57 km downstream of Anyim stream, which is the influent station. The less contamination levels at the two recommended stations entail less elaborate treatments of water and hence reduced costs which makes the treatment more economical.

Table 2: Variation of water quality parameters along Anyim stream due to self-purification

Water quality parameters	Anyim (Influent)	Anyim/Okosi	Okosi/Ahaba	Ahaba/Okporo-akanu	Okporo-akanu/Amaokwe	Critical points
BOD_m (mg/l)	1.000	5.000	6.142	11.672	14.740	
DO_m (mg/l)	9.800	8.714	2.463	4.256	13.895	
DO_{def} (mg/l)	-	1.090	7.337	5.544	0.78	
Time (days)	0.000	0.347	0.347	0.347	0.347	
t_c (days)						4.42
D_c (mg/l)						9.17
t_i (days)						21.68
D_i (mg/l)						31.46
V_{tc} (Km)						114.57

BOD_m= BOD mixture, DO_m = DO mixture, DO_{def} = DO deficit

5.0 CONCLUSION

A study of self-purification capacity of Anyim stream was carried out to assist in making timely decision as in the best location for abstraction of water for treatment and supply to consumers. After the study, it is concluded that effluents from the tributaries adversely affected Anyim stream, though some remarkable degree of self-purification took place along the stream reach. However, the best locations to source for water for treatment and supply to consumers are from a distance downstream of Okporo-akanu/Amaokwe confluence point and 114.57 km away downstream of Anyim stream. This is because water sourced from these locations will require less elaborate methods of treatment and would be cheaper and more economical to manage.

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