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RESEARCH PAPER

THE EFFECTS OF SEWAGE EFFLUENT DISCHARGES ON THE WATER QUALITY OF WUPA RIVER IN ABUJA, NIGERIA

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ABSTRACT

The effect of sewage effluents discharge on water quality of the receiving river in the Wupa area of Abuja was studied to determine the assimilative capacity of the receiving river in event of shock load due to treatment plant failure. The river passes through Idu industrial area of Abuja from where effluent from Wupa sewage treatment plant is discharged. Water samples were taken from six stations along the river reach of 16 kilometres within the vicinity of the treatment plant. Both the effluents and the water samples at six selected points along the river were analysed for pH, electrical conductivity (EC), turbidity, biochemical oxygen demand (BOD) and dissolved oxygen (DO). The results were compared with the standards set by National Environmental Standards and Regulations Enforcement Agency (NESREA) for waste water. The result indicates that the BOD load on the river was within the stipulated limit and there exist a moderate degree of self-purification in the river. The study concluded that the river can withstand BOD shock loadings of up to 44.3 mg/L from the treatment plant without injuring the assimilative capacity of the river.

Keywords: *Water Quality, Biochemical Oxygen Demand, Dissolved Oxygen, Wupa River, Assimilative Capacity*

INTRODUCTION

Water quality monitoring forms an important component of managing the water quality of a river in terms of assessing the health conditions of that river in order to ensure a healthy aquatic environment. Certain water quality indicators such as dissolved oxygen (DO), temperature, biochemical oxygen demand (BOD) etc, need to be determined and compared with specified limits set by regulatory agencies such as the National Environmental Standards and Regulations Enforcement Agency (NESREA, 2011) in Nigeria.

The solubility of oxygen in water for instance, depends on temperature. At high temperature, when bacterial actions are most rapid, the solubility of oxygen is reduced. Hence, conditions in a polluted river usually are worse in warm weather; particularly if it coincides with low flow season (Ogbaji *et al*., 2013).The rate of biodegradation is accelerated or retarded by ambient temperature which affects the values of de-oxygenation and re-aeration rates.

Biochemical oxygen demand (BOD), chemical oxygen demand (COD), total oxygen demand and dissolved oxygen (DO) are the common parameters used in assessing the assimilative capacity of a river. The BOD measures the amount of oxygen utilized by micro-organisms during the oxidation of organic materials (Rao, 2006). It gives an indication of water pollution potential of a given organic waste. The test has its widest application in measuring waste loading to treatment plants and in evaluating the efficiency of such treatment systems.

Water quality of various rivers and streams have been studied and monitored. Akpen and Eze (2006) conducted water quality assessment of River Benue at Makurdi with the aim of using the water quality parameters to develop a model for prediction. Apeh and Ekenta (2012) conducted a study on the surface water quality of Benue River within the reach of the Makurdi brewery. In the study, water quality monitoring was carried out over a period of six months for point and non-point source discharges. The study concluded that pollution in River Benue is influenced by natural regimes such as rainfall and discharges of effluents. Physical and chemical pollutions increased with rainfall while microbial pollution is inversely proportional to rainfall. Similarly, Ogbaji *et al*. (2013) worked on the same river and applied a mathematical model to describe the self-purification of the River Benue, and concluded that self-purification of the polluted river is possible. Ogedengbe and Akinbile (2010) carried out a comparative assessment of industrial and agricultural effluents on the surface water of Ona stream in Ibadan, Nigeria with the aim of identifying major pollutants, their effects on water qualities and to ascertain the potential of using the polluted surface water for irrigation purposes. The result showed that the surface water from the Ona stream was unsuitable for irrigation due to the attendant health hazards associated with the negative effects of pathogens and toxic chemicals in the discharged wastewater.

Adedokun and Agunwamba (2013) modelled the effect of industrial effluents on water quality of River Challawa in Nigeria. The study investigated the physicochemical characteristics associated with industrial effluents from the Challawa and Sharada Industrial Estate in Kano State, Nigeria and the effect on water quality downstream of River Challawa for a period covering wet and dry seasons. The findings identified high BOD load and low dissolved oxygen level, as contributing to a polluted stream with poor assimilatory capacity.

Ubwa *et al*. (2013) carried out assessment of surface water around Gboko abattoir to determine the pollution status of water around the area. The study showed that the values of measured parameters (BOD, DO, etc), were above regulatory standards. The results also showed that the activities at the abattoir were contributing to the pollution load of water in the area, and recommended for close monitoring by the relevant agencies in order to prevent further environmental problems and the attendant health hazards in the future. Chindah *et al.* (2011) carried out a study on the water quality of streams receiving municipal waste in Port Harcourt, Nigeria and found that the levels of DO observed for the study streams were so low as to support aquatic life including fish. The low level oxygen was attributed to the increased concentration of BOD, which tends to swiftly deplete oxygen in the stream.

Paul (2011) studied the impact of industrial effluents on water quality of receiving streams in Nakawa-Ntinda, Uganda with the aim of developing preventive measures. Water quality parameters were assessed and the investigation found that a high degree of pollution in the stream exists and made recommendations on reduction of pollution in the stream. Sharma *et al*. (2003) monitored the water quality of Hathli stream in lower Himalayan Region for parameters of BOD and DO beside others, and established that those parameters were mainly critical during very low discharges.

In Nigeria, the power supply has been quite unsteady. In the event of a disruption in the power supply for one hour, about 1375 m^3 of waste water will enter the Wupa River without treatment which could be dangerous to the river's re-aeration capacity. The water quality was thus investigated to determine the potential of the river recovering in the event of municipal waste spills and the effect on the re-aeration capacity of the river.

MATERIALS AND METHOD

Study area

The study area lies between longitude 7^0 17' 00'' E and 7^0 22' 12''E and latitude 8^0 56' 48''N and 9^0 01' 48''N. The administrative map of the Federal Capital Territory (FCT) depicting the location of the Wupa River is presented in Fig. 1. Wupa River is part of the Jabi River watershed in Abuja. The reach of the river under study covers a total length of 16 km. The river is narrow with maximum dry weather flow width varying from 10 m to 20 m. The river channel bed outcrops indicate medium roughness and the degree of sinusoidality is low to moderate with some few sharp bends. The temperature in the area varies from 27^0C to 36^0C with an average value of 29^0C. Rainfall varied from a monthly depth of 10 mm to 68 mm for the year 2012.

The Wupa Sewage Water Treatment plant is an oxidation ditch type. It was designed to treat waste generated from Abuja city. It has three operating units with one -unit being under operation while the remaining two units are standby in the event of failure of one unit. The

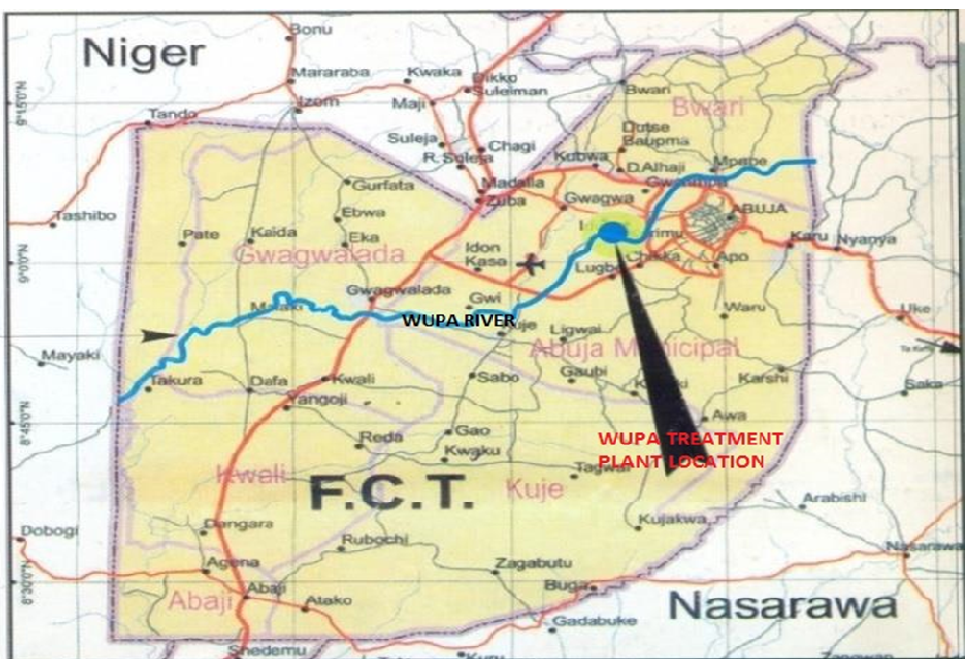

Fig. 1: Administrative map of Abuja showing the location of Wupa River

plants were designed for a full capacity operation of 131,250 m^3 of waste per day, though at the moment, it is operating below designed capacity.

Materials

The materials and equipment used in carrying out the field operation for data collection are listed in Table 1 below.

Sampling locations

Seven sampling points (Numbered ST.1 to ST.6 and STS), were identified and their coordinates determined along the reach of the river (see Table 2). The sampling points were selected based on accessibility to measurement sites. Water samples were collected from each of those sites for water quality measurements. The coordinates of sampling points (determined using Garmin GPS model 60) are given in Table 2 for the month of September, 2012.

Sampling design and method

Samples were collected in September, 2012, which represents the peak rainy season and in January, 2013 for the dry season. Measurements were also conducted in the month of May, 2013, representing the start of the rainy period in the area. Prior to sample collection, 75 centi-litre plastic bottles were washed with dilute acid followed by distilled water and dried at each sampling location. Before collecting samples into the bottles for analysis, they were rinsed twice with the water to be collected. The samples were labelled with date, time and sample location number and taken to the Wupa sewage treatment laboratory for analysis.

Laboratory analysis

The following physico-chemical properties of each water sample were investigated using standard methods (APHA, 1995): temperature, turbidity, conductivity, total dissolved solids, pH, biochemical oxygen demand (BOD) and dissolved oxygen (DO).

Determination of hydrogeometric properties of the River Channel

Hydrogeometric properties of the river determined included flow velocity, depth, cross sectional area and discharge. The discharge was determined using the velocity-area method. The value of K_1 was estimated based on Chin (2006) as indicated in Table 3. K_2 was computed based on Equation 1 (O'Connor and Dobbins, 1958).

$$K_2 = 3.93 \frac{U^{0.5}}{H^{1.5}} \quad (1)$$

Where, U, is the velocity in m/sec and H, is the depth in meters.

The dispersion coefficient (E_x) was calculated

Table.1: Materials used in the study

PARAMETER	MEASURED WITH	USED FOR
DO	Dissolved Oxygen Meter Model 9071	Model calibration
BOD (mg/L)	Respirometer, BOD Bottles, Model OxiTop	Model Calibration
River Temp	Thermometer - Hand held mercury	Calibration of coefficients
Conductivity	Conductivity/TDS meter-DiST3	
Stream Velocity	Floating rubber corks, Measuring Tape, Timer	Model calibration
Depth	Graduated wading rod	Depth Measurement
Elevation	Garmin GPS 60	Slope calculation
Coordinates	Garmin GPS 60	Point identification

Table. 2: Coordinates and elevation of sampling points (GPS)

S/N	Site No.	GPS Coordinates Point Latitude	Longitude	Elevation (m)	Remarks
1	ST.1	0321884	0997488	381	Upstream station of Wupa River before discharge point
2	WTP				Effluent discharge point location
3	ST.2	0321868	0997595	380	Downstream of Wupa river after effluent discharge point
4	STS	0321529	0998645	380	Station at Piqwi village stream
5	ST.3	0321728	0998457	379	
6	ST.4	0318630	0997575	374	Station downstream at Hulumi village
7	ST.5	0312825	0990117	339	Station at Gosa village downstream
8	ST.6	0312825	0990117	305	Under Gosa Bridge by Airport Road, Abuja. Downstream point

Date of Sampling: 19-09-2012
***Key**: WTP = Effluent discharge point location; STS = Test Station; ST.1, ST.2 ... = Station identification number 1, 2, etc*

Table 3: Typical deoxygenation constants

Type of Water	
Untreated Waste water	0.35 - 0.70
Treated Waste water	0.10 - 0.35
Polluted River	0.10 - 0.25
Unpolluted River	less than - 0.05

Source: Chin (2006)

using Equation (2) expressed as:

$$E_x = 2.1xn \times u_x. H^{5/6} \text{ with unit of } m^2/sec \qquad (2)$$

Where, u_x is the longitudinal velocity, H is the depth, and n the manning's roughness.

RESULT AND DISCUSSION

Influent BOD and effluent discharges data from Wupa treatment plant.

The Wupa Sewage treatment plant maintains data base on the waste inflows and the effluent out of the plant. All waste water quality parameters available were collected. However, there was no information regarding the Wupa river flows whether on short or long term. The average daily waste inflows into the plant are indicated in Table 4. Effluent water qualities discharged into the river are given in Table 5. The overall treatment capacity of the plant is 131,250 m^3/day. However, the present treatment plant operates at about one fourth (33,000 m^3/day), of the total plant installed capacity.

Water quality results

The results of the water quality tests are given in Tables 6-8 and Figs. 2 and 3. A comparison of the BOD (Fig. 2) and DO (Fig. 3) for the

Table 4: Influent load into the treatment plant

Parameters		Values (mg/L)
Biochemical oxygen demand (BOD)		180
Dissolved Oxygen (DO)		2.5
Chemical oxygen demand (COD)		400
Total suspended solids (TSS)		170
Total phosphate (TP)		1.2
Nitrate as Nitrogen (NO_3^{-N})		3.25
Actual inflow to plant	33,000 m^3/day	

Source: Wupa Sewage Treatment Plant, WUPA (2012)

Table 5: Effluents load into the Wupa River

Parameters	Value (mg/L)
BOD	1
	1
DO	7-8
COD	25
TSS	13
TP	3.0
NO_3^{-N}	7.0
Actual discharge to river	28,000 m^3/day = 7.778 m^3/s

Source: Wupa Sewage Treatment Plant, WUPA (2012)

Table 6: Field water quality data -19th September, 2012 measurements

Water Quality Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Temperature ^{0}C	27.6	28.0	27.7	27.1	28.0	27.8	27.7
Conductivity (μS/cm)	170	168	168.5	171	170.8	167.7	169
BOD (mg/L)	7.0	10.0	9.0	7.0	9.0	14.0	13.0
DO (mg/L)	8.7	7.8	7.85	8.0	8.05	7.8	7.45
pH	7.43	7.32	7.30	7.25	7.35	7.30	7.25
Saturated DO (mg/L)	7.78	7.83	7.77	7.86	7.83	7.75	7.77
Ultimate BOD (mg/L)	11.1	15.8	14.2	11.1	14.2	22.1	20.6

Table 7: Field water quality data- 20th January, 2013 measurements

Water Quality Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Temperature ^{0}C	26.5	26.5	26.5	27	27	27	27
Conductivity (µS/cm)	217	240	238.5	211.0	223.8	205.7	198
BOD (mg/L)	16	18	17	16	20	21	25
DO (mg/L)	8.1	8.4	8.0	8.1	7.85	7.9	6.95
Saturated DO (mg/L)	8.1	8.1	8.1	8	8	8	8
pH	7.2	7.28	7.23	7.15	7.25	7.20	7.05
Ultimate BOD (mg/L)	25	28.5	26.9	25	31.6	33	39.5

***Key**: STS = Test Station, ST.1, ST.2 ... = Station identification number 1, 2, etc*

Table 8: Field Water Quality Data-17th May, 2013 Measurements

Water Quality Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Temperature ^{0}C	27	27.5	27.8	27.8	28.0	27.8	28.0
Conductivity (µS/cm)	190	170	200.5	189	188	185.8	177.72
BOD (mg/L)	28	25	27	23	18	25	20
DO (mg/L)	5.8	5.6	5.4	5.3	6.3	5.5	5.6
Saturated DO (mg/L	7.83	7.83	7.9	7.8	7.83	7.75	7.82
pH	7.2	6.98	7.2	7.15	7.0	7.0	7.2
Ultimate BOD (mg/L)	44.3	39.5	42.7	36.4	28	39.5	31.5

***Key**: STS = Test Station, ST.1, ST.2 ... = Station identification number 1, 2, etc*

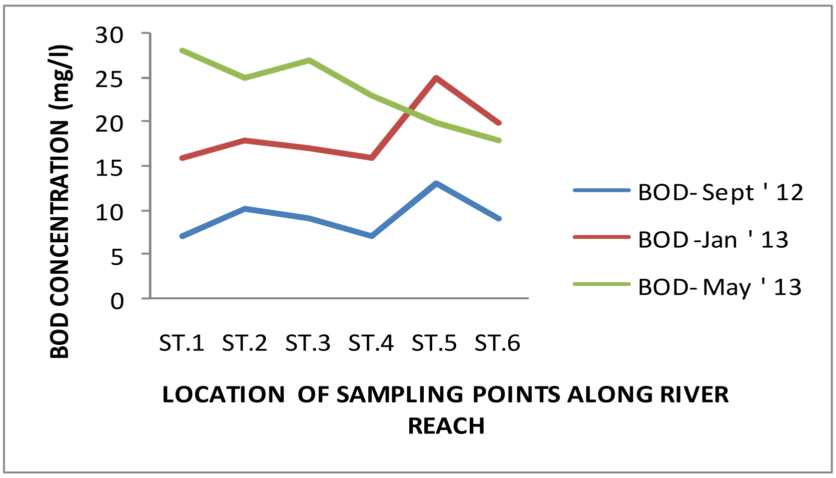

Fig. 2: Curves comparing BOD variation for Sept' 12; Jan'13; May'13

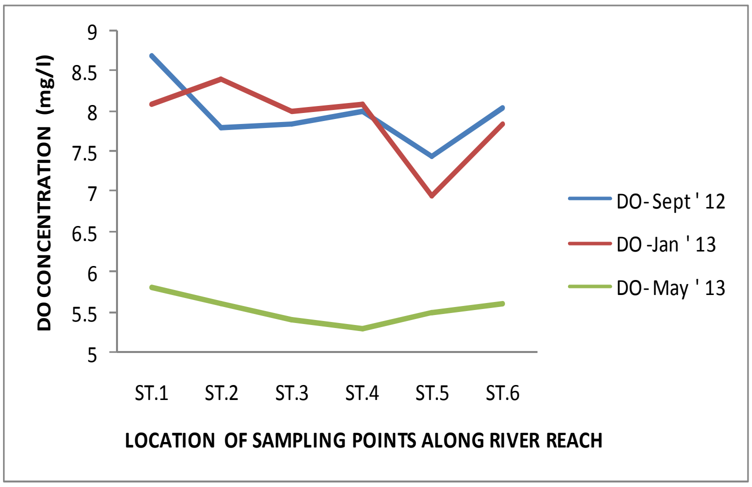

Fig. 3: Curves comparing DO variation for Sept' 12; Jan'13; May'13

months of September, 2012, January, 2013 and May, 2013 indicates that the BOD loads in May, 2013 were higher than those of January, 2013 and September, 2012 at the various stations. This may be due to effect of surface run off occasioned by the onset of rainy season and with the low volume of flow in the river, BOD introduced from the treatment plant was not well diluted compared to the rainy season (September, 2012). The DO in May is lower than that of the other two months corresponding to the high BOD load in the same month.

Hydraulic data

The field hydraulic data collected include the river velocity, the channel width and the depth of river flow. The results of the processed data are summarized in Tables 9-11. From the field measurements, the width of Wupa river channel varies from 5 to 22m during peak flow and 2-12m during normal flow period, the river can be taken as a small river.

Self-purification potential of Wupa River

Self-purification potential is assessed based on the ratio of re-aeration constant to that of the de-oxygenation constant (Agunwamba, 2007; Garg, 1986). From Tables 9-11, the self-purification ratio, f; in all cases exceeded the minimum value of 2 ($17 \leq f \leq 90$) needed to improve the oxygen level in a river. This is an indication that the river possesses high self-purification potential. Thus, Wupa River has a fair assimilative capacity that can withstand some level of unexpected spills from the plant. This ability to undergo self-purification is aided by the presence of rock outcrops and boulders along the river channel.

CONCLUSION AND RECOMMENDATION

From the study, it is concluded that there exists a seasonal variation in the water quality of River Wupa. The BOD loads are higher during dry season than in the wet season, and that the variation is due to dilution process during the rainy season. However, the river possesses high assimilative capacity both in the rainy and dry seasons and can absorb reasonable shock BOD loadings (up to 44.3 mg/L) from the wastewater treatment plant without adversely affecting its water quality. It is recommended that the water quality parameters of Wupa River should be continuously monitored for its oxygen demands

Table 9: River hydraulic parameters-19th September, 2012 measurements

Hydraulic Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Elevation (m)	381	380	379	374	339	305	380
Length (m)	0	502	1000	1510	8000	5000	-
Velocity (m/s)	4	2.3	1.89	2.0	1.5	1.82	1.67
Depth (H) m	0.45	1.5	1.45	1.11	1.25	0.8	0.2
Sect. Area (m^2)	2.1	8.81	12.92	13.51	21.33	15.52	4.17
Flow (m^3/s)	12.39	20.22	24.49	27.07	31.99	28.22	6.95
Re-oxygenation Rate K_2 (per day)	13	3.24	3.1	4.75	3.49	7.41	-
De-oxygenation rate, K_1 (per day	0.20	0.20	0.20	0.20	0.20	0.20	
Dispersion Coefficient (m^2/s)	0.067	0.138	0.122	0.10	0.096	0.084	
Self-Purification Ratio, f(K_2/k_1)	65	16.2	15.5	23.7	17.4	37.01	

***Key**: STS = Test Station; ST.1, ST.2 ... = Station identification number 1, 2, etc*

Table 10: River hydraulic parameters-7th January, 2013 measurements

Hydraulic Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Elevation (m)	381	380	379	374	339	305	380
Length (intervals) (m)	0	502	1000	1510	8000	5000	11000
Velocity, u (m/s)	0.88	3.25	1.80	1.89	1.65	1.39	1.6
Depth (H) m	0.45	0.55	0.65	0.45	0.60	0.80	0.2
Sect. Area, A (m^2)	1.2	2.52	4.88	5.47	6.09	7.6	0.57
Flow (m^3/s)	1.05	8.2	8.79	10.34	10.03	10.56	1.37
Re-oxygenation Rate, K_2 (per day)	12.18	17.37	10.06	9.5	10.85	6.47	17.89
De-oxygenation rate, K_1 (per day)	0.20	0.20	0.20	0.2	0.20	0.20	0.20
Dispersion Coefficient (m^2/s)	0.031	0.071	0.061	0.022	0.055	0.064	0.046
Self-Purification Ratio, f (K_2/k_1)	60	88	50	47	54	32	

***Key**: STS = Test Station,ST.1, ST.2 ... = Station identification number 1, 2, etc*

Table 11: River hydraulic parameters-17th May, 2013 Measurements

Hydraulic Parameters	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	STS
Elevation (m)	381	380	379	374	339	305	380
Length (intervals) (m)	0	500	1000	1500	8000	5000	-
Velocity (m/s)	0.72	0.98	1.3	1.1	1.0	0.9	0.95
Depth (H) m	0.45	0.55	0.65	0.2	0.60	0.80	0.45
Sect. Area (m^2)	1.2	2.52	4.88	0.57	6.09	7.6	5.47
Flow (m^3/s)	1.05	8.2	8.79	1.37	10.03	10.56	10.34
Re-oxygenation Rate K_2 (per day)	7.1	2.6	4.08	3.85	7.0	13.6	13
De-oxygenation rate K_1 (per day)	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Dispersion Coefficient (m^2/s)	0.031	0.043	0.049	0.018	0.053	0.047	0.029
Self-Purification Ratio, f(K_2/k_1)	47	17	27	26	47	90	

***Key**: STS = Test Station; ST.1, ST.2 ... = Station identification number 1, 2, etc*

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