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Impacts of Effluents on the Limnology of a Tropical River, Southwestern Nigeria

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ABSTRACT: The physico-chemical parameters, composition and abundance of macrobenthic invertebrates were studied in River Ogbere, from November 2009 to May 2010. Water samples and macrobenthic invertebrates were collected from three selected sampling sites and analysed using standard methods. The mean biochemical oxygen demand (106.9 ± 58.25 mg/l), Nitrate (40 ± 30.8 mg/l), dissolved oxygen (4.2 ± 2.16 mg/l) and total suspended solids (124.02 ± 16.09 mg/l) were not within permissible standard limits suitable for aquatic life and domestic purposes. Higher concentration of metals was recorded in sediments than surface water. A total number of 563 individuals of macrobenthic invertebrates belonging to 27 genera and four phyla were recorded. The dominant invertebrate in River Ogbere during sampling period was *Chironomus* sp (65.01%). Other pollution tolerant species encountered were leeches (*Pisciola*, 0.36%) and earthworm (*Eiseniella*, 1.95%). The River Ogbere could be regarded as polluted since the adverse water quality has led to presence of mainly pollution tolerant taxa of macrobenthic invertebrates in the waterbed. @JASEM

Keywords: Physico-chemical parameters, metals, Macrobenthos, Tropical River

Rivers are the most important freshwater resources for humans. Social, economic and political development has been largely related to the availability and distribution of fresh water riverine system (Chapman, 1996). In Nigeria, population and industrial centres are increasing; hence there is greater threat of water pollution.

Diverse inputs of pollutants in Ibadan metropolitan area of Nigeria include domestic and industrial waste waters and rainwater which flows through the urban waterways primarily into the three main river systems (Ogunpa, Ona and Ogbere) (Adedokun *et. al*., 2008). Knowledge of the impact of these waste waters on the water resources is required to elucidate their quality and for appropriate mitigation measures to be put in place.

Past works on aspects of limnology of some rivers in southern Nigeria include Victor and Dickson, 1985; Victor and Ogbeibu, 1985; 1991, Olomukoro and Ezemonye, 2000; Arimoro *et al*.,2008 ; Bamikole *et al*.,2009 and Ogbuagu *et al*., 2011) . The only published work on the limnology of Ogbere River is that of Ajani & Morenikeji (2009), and they reported on the effect of cassava effluents on the physico-chemical parameters of Ogbere River.

This study is aimed at providing information on the impact of anthropogenic activities on the physico – chemical factors and benthic macro-invertebrates of Ogbere River for future and effective management of this water body.

MATERIALS AND METHODS

Study area: Ogbere River (latitude 7°26′ 12″N to 7°15′10″N and longitude 3° 57′ 06″ to 3° 52′50″) is one of the three major river basins in Ibadan. Ibadan (Oyo State) Nigeria is the largest city in West Africa and the second largest in Africa with land size covering an area of 24km^2. The city is located on geographic grid reference longitude 3°5′ E; latitude 7° 2'N (Filani, 1994). Ibadan is situated at an average height of 200m above sea level, drained by three major rivers basins (Ogunpa, Ona and Ogbere) and surrounded by secondary rainforest as well as a savanna. Spatially, it sprawls over a radius of 12-15km and experiences a mainly tropical climate with an estimated annual rainforest of about 1250mm (UNCHS/UNEP, 1997).

Three sampling stations were selected across Ogbere River for this study (Fig.1). The sampling stations were established based on human activities, these occur along the whole length of the river.

Station 1 lies between latitude 7° 23' 23" and longitude 3°56' 02". Vegetations found here are banana, cashew, palm and maize plantations. The bank is also overgrown with grasses like *Paspalum* species, *Cyperus* species, and *Vossia* . Activities here include car wash business, and cassava processing factory. This station was dredged in November 2009.

Station 2 is 0.62 km from station 1. Vegetation found here are palm trees, pawpaw, banana plantations, *paspalum* and *Cyperus*. This station receives effluent from cassava processing factory. Dredging took place here in November, 2009.

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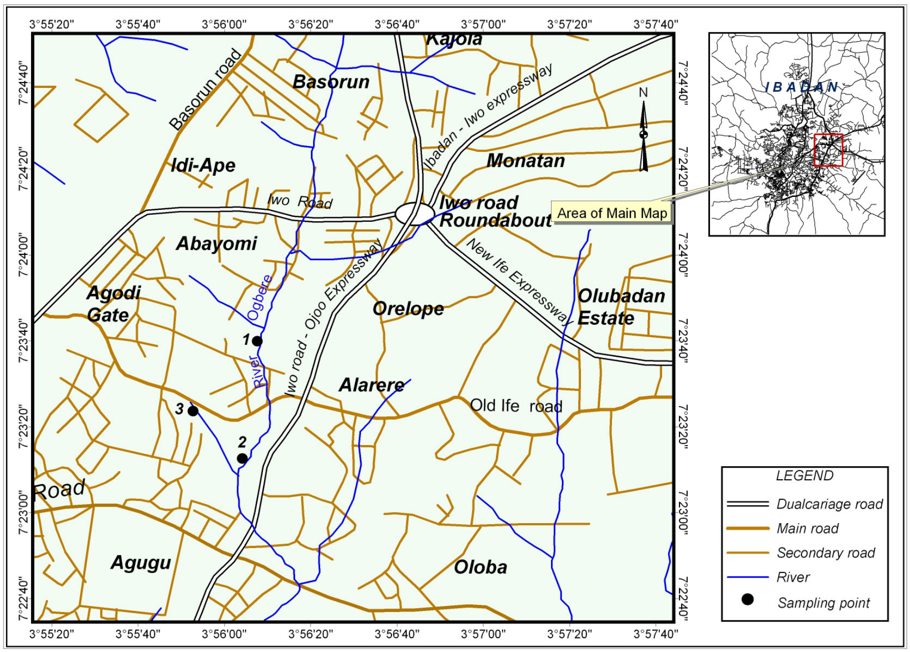

Fig 1: Map of Ogbere River showing sampling stations.

Station 3 lies on a tributary of River Ogbere near where it enters the river. This site is selected since anthropogenic activities occur along the whole length of River Ogbere. It lies between latitude 7^{o} 22' 17" and longitude 3^{o} 56' 08". Vegetations in this site are banana, maize and mango plantations. Domestic wastes are dumped here.

Sample collection and analyses: Sampling for physico-chemical parameters and macroinvertebrates were carried out on monthly basis from November 2009 to May, 2010 except in March 2010. Surface water samples were collected from the sampling stations with specimen bottles and physico-chemical parameters were analysed using standard methods for examination of wastewater described by APHA (1992).

The bottom substratum was collected with a corer (Surface area 0.004m^2). Five replicate core samples were taken from each station. Benthic samples were extracted from 4 hauls and the last haul was used for analysis of soil components and some heavy metals.

The soil sample for extraction of benthos was sieved with 0.5mm mesh size sieve to reduce the bulk, benthos were picked and preserved in 4% formalin, later they were examined under binocular microscope and identified to species level using keys by Pennak (1978) and WHO (1978). Margalef's taxa richness (d), Shannon Index of general diversity (H) and Evenness index (E) were used to analyze the community structure of the macroinvertebrates (Zar, 1984).

The sand, clay, silt and total organic carbon of soil samples were determined using standard methods by APHA (1992). The iron and manganese content were determined with UNICAM Atomic Absorption Spectrophotometer flame atomization Model 969 as adopted from APHA (1992).

ANOVA, Correlation and Principal Component Analysis (PCA) were used to analyse the data.

RESULTS AND DISCUSSION

The spatial variation in mean physico-chemical parameters of River Ogbere, Ibadan is shown in Table 1. The mean temperature of the River Ogbere was 30.03^{o}C ± 1.99 and the surface water temperature indicated that station 3 had the lowest temperature (28.7^{o}C ±1.75). The depth of the water was higher in station 1 (12.9cm ± 4.59). The highest value for turbidity (44.9mg/l ± 2.25), TSS (195.3mg/l ± 36.7) & Total solid (330.6mg/l ± 13.85) were also recorded in station 1 receiving effluents from car wash and cassava processing factory. During the study period, the lowest mean dissolved oxygen concentration was recorded in station 1 (2.88mg/l ± 1.51). Station 3 had the highest BOD level (69.2mg/l ± 22.17) and lowest value was recorded in station 1 (51.6mg/ ± 29.8). There was gradual decrease in phosphate, nitrate and total hardness of the water from station 1 to 3. The concentration of iron was highest in station 2 (1.18mg/l ± 1.5) and lowest in station 3 (0.45mg/l ± 0.37).

The Principal Component Analysis (PCA) revealed that four components formed the extraction solution and explains 79.002% of the variability in the original 16 variables, with only about 21% loss of information (Table 2).

Table 1: Spatial variation in mean physico-chemical parameters of River Ogbere, Ibadan

Parameters	Station				ANOVA	
	1	2	3	Mean	F – value	
Temperature (°C)	31.17± 1.96	30.25 ±2.72	28.67± 1.75	30.03 ±1.99	2.01	P>0.05
pH	8.70 ±0.54	8.63 ±0.53	8.31 ±2.71	8.54 ±0.29	1.18	P>0.05
Water depth (cm)	12.90 ±4.59	10.73 ± 5.31	6.56 ±2.52	10.06 ±3.61	3.37	P>0.05
BOD (mg/l)	51.63± 29.80	53.95 ±52.21	69.17± 22.17	58.25 ±33.50	0.40	P>0.05
Turbidity (NTU)	44.92± 2.25	17.13 ±7.26	20.41± 6.69	27.49 ±4.88	40.52	P>0.01*
Nitrate (mg/l)	33.96 ±2.58	30.44 ±7.34	27.99 ±8.73	30.80 ±5.52	1.18	0.05
Phosphate (mg/l)	0.32 ±0.12	0.23 ±0.39	0.23 ±0.17	0.26 ±0.16	0.25	P>0.05
Total Hardness (mg/l)	183.33±28.05	165.00 ±54.68	160.00±23.66	169.45±31.65	0.63	P>0.05
Total suspended solids(mg/l)	195.31 ±36.72	94.85 ±38.33	81.91 ±29.15	124.02±16.09	18.92	P>0.01*
Total dissolved solids (mg/l)	135.33 ±40.91	194.11± 5.21	236.18±15.35	188.54±12.45	24.28	P>0.01*
Total Solid (mg/l)	330.63 ±13.85	284.63±47.35	318.09±23.97	311.12±27.35	3.38	P>0.05
Conductivity (µs/cm)	135.50± 41.14	192.33 ±24.91	160.33±36.76	162.71±23.58	4.00	P>0.05*
COD (mg/l)	171.27±107.37	171.42±149.76	219.71±71.68	189.30±105.19	0.35	P>0.05
Dissolved Oxygen (mg/l)	2.88 ±1.51	4.51 ±3. 60	5.11 ±2.82	4.18 ±2.16	1.05	P>0.05
Iron (Fe)(mg/l)	0.795 ±0.89	1.18± 1.50	0.45 ±0.37	0.81 ±0.61	0.75	P>0.05
Manganese (Mn) mg/l)					0.66	P>0.05

* indicated significant difference; Manganese occurred in station 1 (0.80mg/l ± 0.14).

The first component explained about 36.49%, the second 19.62%, the third 14.28% and the fourth 8.61% of the variability. The scree plot (Fig.2) shows the extracted components on the steep slope, while the components on the shallow slope contributed little (21%) to the solution. The rotated component matrix (Table 3) revealed that the first component was most highly correlated with BOD (0.965), the second with TSS (0.932), the third with Manganese contents (0.915) and the fourth with DO (-0.760).

Table 3: Rotated component matrix of the physicochemical variables of Ogbere River, Ibadan

Parameter	Components			
	1	2	3	4
BOD	0.965			
TSS		0.932		
Mn			0.915	
DO				-0.760

A total number of 563 individuals, occurring in 27 genera and four phyla were encountered during period of study (Table 4). The dominant macroinvertebrates were *Chironomus* sp. (65.72%) and largest number (225/65.9%) occurred in station 2 that received discharge from cassava processing factory. However, *Chironomus* formed 86.6% of benthos in station 3. The gastropods were more abundant in station 1(34.3%) represented by 11 species and station 2 (24%) represented by 13 species than station 3 (1.22%) where it is represented by only one species, *Melanoides tuberculata*. Species were more diverse in station 1 (H^1 = 1.82) than station 3 (H^1 = 0.88). The macroinvertebrates species showed more eveness in station 1 than other two stations. Species was highest in station 2 (3.77) and lowest in station 3 (0.84) Fig. 3. The correlation coefficient (r) between physico-chemical parameters and benthos macroinvertebrate is shown on Table 5. Gastropoda was negatively correlated with temperature, water depth, BOD, turbidity, nitrate, phosphate, TSS, COD and manganese. Members of the Class Insecta were negatively correlated with pH, iron and manganese. Oligochaetae correlated negatively with water depth, turbidity, nitrate, phosphate, TSS, iron, manganese and correlated positively and significantly with D0.

Soil analysis**:** The highest mean concentration of Fe (89.2mg/l ± 27.14) and Mn (7.3mg/l ± 4.94) were recorded in substratum of (station 1) and least concentration of Fe (31.9 ± 4.2) and Mn (3.96mg/l ± 0.58) occurred in station 3. There was gradual decrease in the concentrations of both metals from dry season months (November to February) to raining season months (April to May), Table 6. Sand form the highest proportion of the soil in all the stations followed by silt, however there was no clay in station 3 (Fig.4).

The mean temperature, DO, COD, TSS, pH, BOD, Nitrate, Fe and Mn obtained during this study are not within permissible standard limits (Hynes 1970, 1971, WHO, 1984 and FME, 2001). This indicates that the river is polluted and may not be suitable for sensitive / intolerant aquatic species and domestic purposes. The high water temperature can be as a result of absorbance of heat by the large amount of suspended solids (contributed by the cassava peels and domestic wastes discharged into the water). Aerobic decomposition of organic matter by bacteria, which is an important drain on oxygen supplies (Boyd, 1979) together with the high TSS recorded which indicates the water is turbid may also result in low DO of the surface water of Ogbere River due to reduced photosynthetic activities.

The PCA also indicated total suspended solids being the most correlated with the second component extracted and high TSS in aquatic system can cause several problems to the aquatic biota. Contents of some solids (i.e. pesticide) and other industrial waste can damage the physiology of fish. The suspended solids can also clog the fish gills, reduce growth rates, decrease resistance to diseases and prevent egg and larval development possibly through suffocation (Murphy, 2007).

Table 4: Composition, distribution and abundance of benthic macro invertebrates of River Ogbere, Southwestern Nigeria.

Taxa	Station 1	Station 2	Station 3	Total
Phylum Mollusc*a* Class Gastropoda				
Afropomus balanoides	1(0.71)	-	-	1(0.18)
Bulinus globosus	2(1.43)	1(0.29)	-	3(0.53)
B. rohfsi	2(1.43)	4(1.17)		6(1.07)
B. camerunensis	1(0.71)	3(0.88)	-	4(0.71)
B. forskalii	1(0.71)	1(0.29)	-	2(0.36)
Gabiella africana	-	2(0.59)	-	2(0.36)
Hydrobia accrensis	1(0.71)	2(0.59)	-	3(0.53)
H. guyenoti	-	2(0.59)	-	2(0.36)
Aplexa spp.	8(5.71)	28(8.21)	-	36(6.59)
Lymnea natalensis	-	2(0.59)	-	2(0.36)
Melanoides tuberculata	1(0.71)	-	1(1.22)	2(0.36)
Physa marmorata	23(16.43)	28(8.21)	-	51(9.06)
Pila africana	4(2.86)	2(0.59)	-	6(1.07)
Potadoma liberiensis	-	2(0.59)	-	2(0.36)
Pseudocleoptra togoensis	2(1.43)	5(1.47)	-	7(1.24
Fragments	2(1.43)	-	-	2(0.36)
Phylum Arthropoda Class Insecta				
Order Coleoptera				
Helmis	-	1(0.29)	-	1(0.18)
Order Diptera				
Chironomus larva.	72(51.43)	227(66.67)	71(86.6)	370(65.72)
Chaoborus larva	3(2.14)	-	-	3(0.53)
Tipula larva	-	1(0.29)	-	1(0.18)
Simulium larva	-	3(0.88)	-	3(0.53)
Phylum Platyhelminthes Class Turbellaria				
Planaria	-	1(0.29)	-	1(0.18)
Phylum Annelida Class Hirudinea				
Pisciola	-	2(0.59)	-	2(0.36)
Class Oligocheata				
Lumbriculus	9(6.43)	18(5.28)	3(3.66)	30(5.33)
Eiseniella	-	4(1.17)	7(8.54)	11(1.95)
Fragment worms	8(5.71)	2(0.59)	-	10(1.98)
Total No of individual	140	341	82	563
Total No. of taxa	14	21	4	24

Table 5: Correlation coefficient (r) values between physico-chemical parameters and macroinvertebrates of River Ogbere, Southwestern Nigeria

Parameters	Gastropoda	Insecta	Oligocheata
Temperature (^oC)	-0.29	0.34	0.31
pH	0.43	-0.30	0.01
water depth (cm)	-0.05	0.31	-0.10
BOD (mg/l)	-0.10	0.61	0.31
Turbidity (NTU)	-0.21	0.07	-0.27
Nitrate (mg/l)	-0.13	0.29	-0.02
Phosphate (mg/l)	-0.20	0.26	-0.13
Total Hardness (mg/l)	0.04	0.60	0.24
Total Suspended Solids (mg/l)	-0.05	0.13	-0.08
Total Dissolved Solids (mg/l)	0.09	0.17	0.16
Total Solid (mg/l)	0.07	0.45	0.10
Conductivity (µs/cm)	0.38	0.08	0.04
COD (mg/l)	-0.08	0.62	0.28.
Dissolved Oxygen (mg/l)	0.60	0.58	0.70*
Iron (Fe)(mg/l)	0.13	-0.23	-0.23
Manganese (Mn) mg/l)	-0.06	-0.31	-0.30

* Indicate significant at P<0.05.

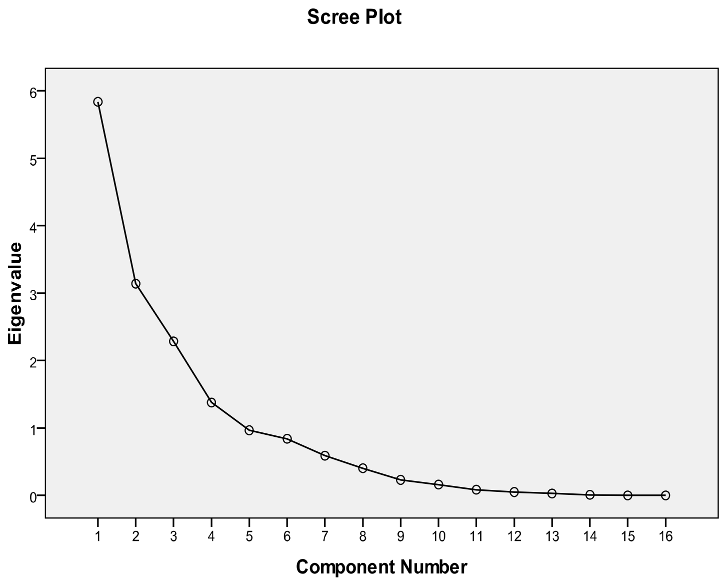

Fig.2: Scree plots of eigenvalues of initial component

Also, high BOD of the water could be due to organic matter discharged into the water body, leading to the growth of decomposer organisms on them. In addition, the PCA identified BOD as the most important factor responsible for variations observed in the data, thus there is need for action to be taken to prevent organic materials from being dumped in the river. Arimoro *et al*., (2008) and Ajani and Morenikeji (2009) also affirmed that cassava effluent led to high BOD in surface water bodies. According to Jonnalagadda and Mhere, (2001), BOD values indicate the extent of organic pollution in aquatic ecosystems which adversely affects water quality and high BOD is an index of organic pollution (Egborge, 1970). Introduction of car wash effluent, petrol, detergents and smoke from silencers may result in the high metal concentration of the water. Higher metal concentration of the sediment recorded can lead to the transfer from sediments to the biota and benthic organisms are likely to be the most directly affected by the metal concentration in the sediments because the benthos is the ultimate repository of the particulate materials washed into the aquatic systems. This was also reported by Campbell and Tessier, 1991.

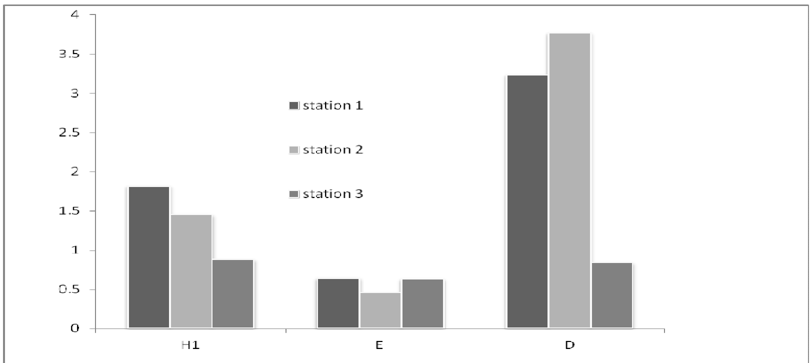

Fig 3 : Spatial Biodiversity of Benthic Macroinvertebrates of River Ogbere Ibadan

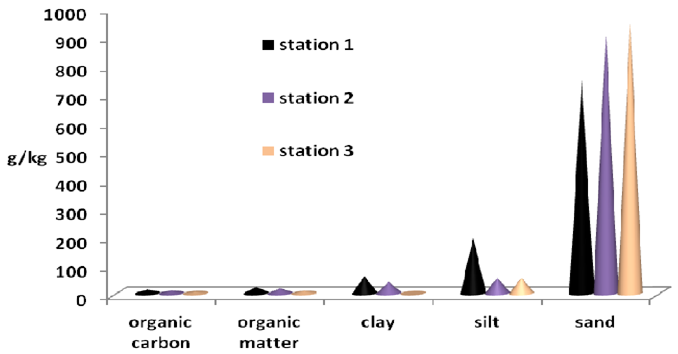

Fig 4 : Spatial variation in the soil component of River Ogbere Ibadan

The presence of the pollution tolerant taxa, Midge larva (*Chironomus* sp.) *Lymnea natalensis* (Moog and Chovanec, 2000; Adakole and Annune, 2003) could be attributed to the effects of domestic and industrial wastes on the river. The adaptation of *Chironomus* sp. includes possession of pigment hemoglobin by most of its species, which gives it affinity for oxygen (Mason, 1991). The absence of molluscs in station 3 except for *Melanoides tuberculata* may be as a result of lack of clay content in the sediment. According to Wharte (1977), the finer clay/silt particles had a higher water retaining capacities (42 to 66% water content) compared with more coarse sediments (28 to 49% content). The water retaining capacity can be important for burrowing invertebrates during periods of exposure.

Table 6: Spatial and seasonal variation of iron and manganese contents in the soil of River Ogbere, Southwestern Nigeria

Months	Iron (mg//l)				Manganese (mg//l)			
	1	2	3	Mean ±S.D	1	2	3	Mean ±S.D
November	99.70	48.00	31.60	59.77±35.54	18.80	10.32	3.44	10.55±7.69
December	110.2	57.20	32.30	66.57±39.79	22.30	9.65	4.87	12.27±9.01
January	107.2	52.40	39.90	66.50±35.80	17.31	12.95	4.11	11.46±6.73
February	87.30	66.10	29.10	60.83±29.46	19.30	5.45	3.43	9.39 ±8.64
April	94.50	60.20	30.30	61.67±32.13	18.25	7.30	3.55	9.70 ±7.64
May	36.50	30.20	28.20	31.63 ±4.33	7.83	4.17	4.33	5.44 ±2.07
Mean	89.23±27.14	52.35±12.52	31.90±4.20	57.83±13.16	17.30±4.94	8.31 ±3.28	3.96 ±0.58	9.85 ±2.41

The high species diversity and species richness in stations 2 and 3 shows that the organisms were tolerant to pertubation arising from human activities. This was also observed by Ikomi *et al.*, 2005. The negative correlation obtained between those physico-chemical parameters that exceeded the permissible standard level and benthic macroinvertebrates shows that although these parameters favoured the preponderance of the tolerant species, the prevailing environmental factors are not the optimum conditions for these macroinvertebrates.

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