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Water and Planktonic Quality of a Palm Oil Effluent Impacted River in Ondo State, Nigeria

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Abstract: The planktonic and water quality of River Oluwa, Ondo State, Nigeria, under continuous perturbation from oil palm processing effluents were assessed at Oluagbo, Ebute-Ire and Araromi-Ayeka locations between April and September 2003. Water samples collected from the study sites were in the slightly acidic range (pH 6.45-6.75) with a mean alkalinity ranging between 30.1±4.6 and 38.5±3.8 mg L^{-1}. The dissolved oxygen content of water rarely went below 3.0 mg L^{-1} and rarely above 7.0 mg L^{-1} irrespective of sampling location. Quantitatively, the levels of Fe and Cu with a mean concentration ranging between 3.07±1.58 and 10.35±3.33 mg L^{-1} were the major elements in the water sample while Na, K, Ca, Mg with mean concentrations between 1.05±0.02 and 4.10±1.65 mg L^{-1} were the minor elements. Irrespective of the site of sample collection on the river, the concentrations of Cr, Ni, Pb and P (<1.0 mg L^{-1}) occurred in trace amounts. The phytoplanktonic flora of River Oluwa showed an extensive overlap between the sites due to homogenous climatic and environmental conditions. The recorded taxa consists of ten chlorophytes, five species of diatoms, three cyanophycean species and one euglenophyte. The zooplanktonic fauna consists of six species of rotifers. *Spirogyra fluviatilis* and *Ulothrix zonata* were the dominant green algae (Chlorophyta) irrespective of the location while *Synedra sp.* and *Fragillaria crotonensis* were the dominant diatoms (Bacillariophyta). Quantitatively, samples collected from the Oluagbo and Ebute-Ire locations had significantly higher ($p<0.05$) planktonic abundance than samples collected from the Araromi-Ayeka location.

Key words: Oil palm, effluent, water quality, plankton, flora, fauna, species diversity

INTRODUCTION

Oil palm is a major tree crop endemic to areas between the coastal rain forest of Southern Nigeria and the Guinea savannah belt in the north (latitudes 4°N and 11°N). Palm oil, the world's main edible oil[1] is derived from the fruits of oil palm tree (*Elaeis guineensis*) which is a sessile drupe[2]. The wild oil palm grove in Nigeria is currently estimated at 2.1 million ha[3]. The cultivated palm tree estate and small holdings accounted for 81, 475 and 105, 184 ha, respectively[4]. By inference, the figures roughly translated to about 80% of Nigerian oil palm resources existing in small holder's plantation[5].

The techniques for expulsion of crude oil from palm fruits and the purification of the expellates vary with available technology. The extraction of palm oil from freshly harvested palm fruit bunch (FFB) involves fruit loosening, sterilisation, digestion, oil expression and clarification[3,6]. The prevalent traditional manual pit aqueous extraction technology is primarily utilized by the local processors. Traditional sterilization of the fruit is done in metal drums over an open fire each with about 200 Litres of water[5]. During digestion, cooked palm fruits are broken up for easy oil separation from fibre and the resultant mash is flushed with water. A mixture of oil and water obtained is later clarified to separate oil from water and other contaminants[7].

A common feature of most local palm oil processing outfits is their remote location usually contiguous to a perennial water source. Drainage facilities are usually absent at such locations and there is no settling tank for collecting the coloured wastewaters and concentrated sludge mixed with fibre[5]. At the end of a typical working day, the palm oil press is washed with soap and the wastewater is directed outside into the riparian environment[8].

The problem of palm oil mill effluent pollution is unique to Nigeria for a number of reasons. No established control methods are possible because local palm oil mills located in nooks and crannies are unlicenced and without quality control. Palm oil effluent treatment technology is non-existent and the prescribed environmental regulations on the allowable pollution loads are un-enforceable due to inadequate logistics for enforcement. Minimisation of effluent quantity is not pursued in the traditional palm oil mills and effluent utilization is not practicable. Sound water quality objectives to reduce the level of pollutants in the effluents are not pursued because of lack of

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awareness on the aquatic pollution problems being created.

The processes involved in extraction of palm oil from Fresh Fruit Bunches (FFB) requires large amount of water. With correct operation, about 2.5 tonnes of effluent would be generated per tonne of crude palm oil processed[9]. The highly polluting effluent when fresh, is an acidic colloidal suspension characterized by high concentration of suspended solids, with a Biological Oxygen Demand (BOD) of 25,000 ppm and a Chemical Oxygen Demand (COD) of 60,000 ppm[10]. The brownish colour of palm oil mill effluents presumably arose from breakdown products of carotenoids[11].

Riparian rivers and streams receiving palm oil mill wastewaters are expected to be heavily polluted. The flora and fauna in such a waterway are expected to be detrimentally affected thus creating serious conservation problems for such impacted aquatic ecosystem. Therefore this study was designed to document the water and planktonic quality of River Oluwa which is the largest river draining the richest palm oil producing belt of Ondo State, Nigeria.

MATERIALS AND METHODS

Study sites: The old Okitipupa Region (Latitudes 6° 29' 00 N 6°32' 00 N and Longitudes 4°41' 43 E 4°52' 08 E) is the main palm oil producing belt of Ondo State, Nigeria. The oil palm grove is primarily drained by River Oluwa which had Rivers Ofara (6°29'04 N 4°44' 44 E) and Erinodo (6°29' 64 N 4°44' 02 E) as its main tributaries. At the peak of rainy season when River Oluwa is swollen with flood water, the length of the river is rarely less than 50 m across. Other small annual and perennial streams which are usually ponded for palm oil producing activities characterize River Oluwa drainage basin. Climatic factors which favour the growth of palm tree within the belt include extended raining season between the months of April and November with a mean annual precipitation ranging between 2000 and 2500 mm[12].

Water and planktonic samples were collected from Oluagbo (6°31' 10 N 4°47' 58 E); Araromi-Ayeka (6°29'.09 N 4°50'.00 E) and Ebute-Ire (6°29' 12N 4°47'. 59 E). All the sampled locations are contiguous to farm settlements at the bank of River Oluwa.

Water quality and planktonic analyses: Sub-surface water samples which were collected bi-monthly with a Friedinger water sampler between April and September, 2003 were analysed for some physico-chemical characteristics. Sample collection was done to coincide with the period when palm oil processing in the area of study is at its peak[5]. The pH of the collected sample was done *in situ* using a HACH portable water laboratory. The collected samples were subsequently field preserved to retard the expected chemical changes[13].

The preserved water samples were laboratory analysed for the alkanity level, organic matter and the dissolved oxygen contents and the Biological Oxygen Demand (BOD)[13]. The concentrations of Ca^{2+}, Zn^{2+}, Cu^{2+}, Mn^{2+}, Mg^{2+}, Pb^{+}, Fe^{2+}, P^{3+}, Ni^{2+}, Cd^{+} and Cr^{2+} were determined by atomic absorption spectrophotometry using Zeeman Flameless Atomic Absorption Spectrophotometer. Na^{+} and K^{+} levels were determined using flame photometric method[14].

Quantitative and qualitative planktonic evaluation were also carried out on water samples collected from designated locations during the period of study. Thirty litres of the sample collected was concentrated to 20 mL by filtration through a 45 μ plankton net. The plankton concentrate was then preserved with Lugol solution pending microscopic examination in the laboratory. One millilitre of the preserved plankton concentrate was introduced into a Sedwick-Rafter plankton counting chamber for examination under an Olympus BH2 Microscope. Planktonic identification and enumeration were done where possible to specific level accordingly[13,15]

Statistical analysis of data was carried out with SPSS statistical package programme while Kruskall-Wallis one-way ANOVA was used to compare data among stations.

RESULTS

Water quality: Irrespective of the sampling points on Oluwa River during the period of study, samples collected were in the slightly acidic range with a mean alkalinity ranging between 30.1 and 38.5 mg L^{-1} (Table 1). The mean organic matter contents were relatively low with a median value of 2.7±0.6 mg L^{-1} (Araromi-Ayeka location) while the mean Biological Oxygen Demand (BOD) ranged between 1.8±0.5 and 3.2±1.6 mg L^{-1}. During the period of samplings, the dissolved oxygen content of water rarely went below 3.0 mg L^{-1} and rarely above 7.0 mg L^{-1} irrespective of the location.

Results on the assay of elements in the water samples showed that iron and copper with concentrations ranging between 3.07 and 10.35 mg L^{-1} could be regarded as major elements (Table 1). Sodium, potassium, calcium and magnesium whose mean concentrations ranged between 1.05 and 4.10 mg L^{-1} were minor elements, chromium, nickel, lead and phosphorus with concentrations below 1.0 mg L^{-1} in the water samples could be regarded as trace

Table 1: Mean±SD of some water quality parameter of the sampled locations on River Oluwa

Parameter	Oluagbo	Araromi-Ayeka	Ebute-Ire
Physico-chemical			
pH	6.75±1.0	6.45±0.8	6.55±1.2
Alkalinity (mg L^{-1})	38.5±3.8	31.0±4.6	30.1±5.3
Organic matter (mg L^{-1})	2.20±1.1	2.7±0.6	2.9±0.9
Dissolved oxygen (mg L^{-1})	3.4±1.1	5.3±2.6	5.0±1.8
Biochemical			
Oxygen demand (mg L^{-1})	2.6±0.8	3.2±1.6	1.8±0.5
Metals (mg L^{-1})**			
Sodium (Na^+)	2.80±0.65	4.10±1.65	2.65±0.55
Potassium (K^+)	3.35±0.10	1.80±0.25	2.00±0.50
Calcium (Ca^{2+})	1.75±0.01	1.05±0.02	2.15±0.06
Magnesium (Mg^{2+})	1.32±0.001	1.65±0.002	1.34±0.001
Iron (Fe^{2+})	10.35±3.33	5.10±1.18	10.05±4.20
Copper (Cu^{2+})	4.74±1.12	5.63±2.59	3.07±1.58
Chromium (Cr)	0.03±0.02	0.04±0.02	0.06±0.01
Nickel (Ni^+)	0.85±0.30	0.24±0.10	0.56±0.21
Lead (Pb^+)	0.08±0.03	0.07±0.01	0.09±0.04
Phosphorus (P^{3+}	0.06±0.001	0.02±0.007	0.05±0.001

**The levels of Manganese, Zinc and Cadmium in the water samples were below the detection limit of the AAS used for the analyses.

Table 2: Planktonic species composition and abundance (Cell/m^3 x 10^3) in the sampled locations on River Oluwa

Taxa	Oluagbo	Araromi-Ayeka	Ebute-Ire
Phytoplankton			
Cyanophyta (Blue Green Algae)			
Anaebena variabilis	45	112	80
Microcystis incerata	45	20	31
Sphaerocystis schroeteri	249	110	250
Chorophyta (Green Algae)			
Ankistrodesmus falcatus	30	15	42
Cladophora glomerata	30	10	14
Closterium elongatum	15	60	37
Closterium lanceolatum	30	127	110
Hydrodictyon reticulatum	10	-	18
Scenedesmus quadricauda	42	30	21
Spirogyra fluviatilis	23980	9005	18430
Staurastrum sp.	55	75	47
Stigeoclonium proteusum	600	155	285
Ulothrix zonata	20900	6225	18045
Bacillariophyta (Diatoms)			
Asterionella sp.	15	30	45
Fragilaria crotoneusis	4500	1600	8000
Navicula pelliculosa	75	37	68
Rivularia haematites	15	-	-
Synedra sp.	1681	1501	4403
Euglenophyta (Euglenoids)			
Trachelomonas planctonica	-	15	10
Zooplankton			
Rotifera (Rotifers)			
Argonotholca sp.	-	15	5
Asplanchna priodonta	-	30	10
Lecane (monostyla) bulla	-	15	-
Leane (lecane) curvicornis	-	10	-
Lecane luna	30	15	40
Trichocerca ruttneri	-	15	12
Species richness	19	23	22
Species diversity index (H')	1.05	1.46	1.28

elements. The levels of manganese, zinc and cadmium were found to be below the detection limit of the equipment used for the determination. Variations were recorded in elemental levels between the study sites. The order of magnitude of concentration of the assayed metals in the water samples from the Oluagbo location was Fe>Cu>K>Na>Ca>Mg>Ni>Pb>P>Cr while from the Araromi-Ayeka site it was Cu>Fe>Na>K>Mg>Ca>Ni>Pb>Cr>P. At Ebute-Ire site, the order of magnitude of concentration was Fe>Cu>Na>Ca>K>Mg>Ni>Pb>Cr>P. In spite of the differences recorded in the concentration of elements between the study sites, the observed differences were found not to be statistically different ($p>0.05$).

Phytoplankton: The phytoplanktonic flora of River Oluwa during the period of study consisted of the blue green (Cyanophyta), the green (Chlorophyta), the diatoms (Bacillariophyta) and the euglenoids (Euglenophyta) (Table 2). The green algae which had the highest species richness was represented by ten species. Relatively, the diatoms with five species was the next important algal group while the blue green algal species were represented by three species.

The dominant chlorophytes which feature most prominently in all the sampled locations were *Spirogyra fluviatilis*, *Ulothrix zonata* and *Stigeoclonium protensum*. *Sphaerocystis schroeteri* dominated the blue green algal flora while *Synedra* sp. and *Fragillaria crotonensis* were the dominant diatomic species. *Trachelomonas planctonica* the only euglenoid recorded occurred only in samples collected from Araromi-Ayeka and Ebute-Ire.

Qualitatively, Araromi-Ayeka and Ebute-Ire planktonic samples were relatively richer (with 23 and 22 species respectively) than those of samples from Oluagbo location (19 species). The Diversity Indices of samples from Araromi-Ayeka and Ebute-Ire were also higher (1.46 and 1.28, respectively) compared to those of samples collected from Oluagbo (1.05). Quantitatively however, samples collected from Oluagbo and Ebute-Ire locations had significantly higher ($p<0.05$) planktonic abundance than samples collected from Araromi-Ayeka location. Samples from the two locations were predominantly *Sphaerocystis schroeteri*, *S. fluviatilis* and *U. zonata*, *E. crotonensis* and *Synedra* sp.

The zooplanktonic fauna of River Oluwa which consisted of six rotiferic species was dominated by *Lecane luna*. All the recorded rotifers occurred at Araromi-Ayeka location, while four and one species respectively occurred at Ebute-Ire and Oluagbo locations.

DISCUSSION

A profound relationship has been established between water chemistry and frequency of flora. The chemical environment of water which however is less constant is dependent on the topography, nature of inflowing streams, autochthonous production within the waterbody and variation in the soil type. Irrespective of the source of the variation, water physico-chemistry exerts a great effect on the aquatic flora especially on the river potamoplankton. Sodium, potassium, calcium and magnesium must be present in adequate amount to facilitate optimal algal growth 6]. Most algae are also known to tolerate a pH in the range of 6.8-9.6[17].

The concentrations of Fe, Cu, Na, K, Ca, Mg were elevated relatively at the various study sites while the corresponding levels of P were low during the period of study. The origin of high levels of copper and iron in the river water could however not be ascertained. Likely sources of the elements which needed to be further investigated however include natural soil weathering processes and anthropogenic contributions from palm oil manufacturing. Iron in higher concentrations which probably contributed to the sedimentation of phosphorus will have negative consequences on aquatic flora[18] as optimal algal growth is dependent on presence of a minimal amount of P[17]. The low concentration of P might also be due to their preferential accumulation by filamentous green algae which were the dominant phytoplankton at the different study site[19] .

The relatively elevated concentration of some assayed elements in the Oluwa River samples coincided with period of highest pluviosity over the area which promotes nutrient inputs through percolation and run-offs[12]. The input of nutrients into River Oluwa including those from palm oil manufacturing during the period of study also included contributions from tributaries and distributaries in the drainage basin. The consequences of nutrients liberated into River Oluwa water column probably favoured the growth of opportunistic species like small Chlorococcales and Zygnemaphyceae adapted to high turbulence and high nutrient inputs during the rainy period[20] at the expense of species sensitive to contaminant inputs from the basin[21].

The phytoplanktonic flora recorded for River Oluwa are typically those of flowing rivers dominated by diatoms and chlorococcalean green algae[22]. The minimal diversity of the cyanophycean flora was probably because cyanobacteria are not characteristically elements of river phytoplankton[23]. Also, the presence of relatively high concentration of calcium in the river water known to inhibit the growth of cyanophycean flora[24] could also be responsible for the low species diversity.

The overlap recorded in planktonic composition of the sampled sites on River Oluwa could be attributed to homogenous climatic events and environmental conditions over the area which generated the same configuration of abiotic and biotic factors. The occurrence of some sensitive genera at the various sites during the period of study was probably due to some peculiar characteristics possessed by the species[21]. The occurrence might also be due to recruitments from other habitats during period of high mixing or as a result of tributary inputs[25].

Spirogyra fluvitilis and *Ulothrix zonata* are Filamentous Green Algae (FGA) dominant in planktonic samples from River Oluwa. FGA blooms are biological indicators of water quality disturbances[19,26-28] because FGA serve as sinks for accumulation of C, N, P[29]. The dominance of two FGA species therefore is an indication of the river water quality impairment. The only anthropic activity that could result in aquatic perturbation within the predominantly rural study area are the untreated oil palm mill effluent discharges into the environment by cottage palm oil processing mills.

The raw effluents being discharged into the aquatic environment are acidic, brownish colloidal suspension characterized by high suspended solid load and COD[9]. The brownish colour presumably arose from breakdown products of carotenoids. The slightly acidic nature of the river water could have resulted from uncontrolled effluent discharges into the tributaries and the distributaries feeding River Oluwa. The colloidal suspension in the effluent discharges will likely increase turbidity and reduce transparency of water. The net effects of such reduction is impairment of algal photosynthetic activities through decrease in the depth of the photic zone.

Deleterious effect of uncontrolled oil palm mill discharges on the fauna probably manifested as near absence of zooplanktons. Rotifers which are herbivorous centrifugators[30] were mostly represented at a location. The rotiferic species recorded show vagility with a strong capacity for colonization. Their composition and abundance in the river system could be attributed to ecological segregation related both to feeding behaviour and susceptibility to contaminants[31] since the principal energy pathway through a predator-prey planktivory oriented food web is usually controlled by the size, quality and abuandance of phytoplanktons[32]. The dominance of *Spirogyra fluviatilis* and *Ulothrix zonata* also confirmed the absence of powerful zooplanktonic grazers for the two species in the river. The implication of the dominance of the two FGA are that they are not sources of energy for benthic and planktonic herbivores[33].

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