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EFFECTS OF CASSAVA EFFLUENT ON BENTHIC MACROINVERTEBRATE ASSEMBLAGES IN A TROPICAL STREAM IN SOUTHERN NIGERIA

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Abstract. The study of the effect of cassava effluents on macroinvertebrates along downstream reaches of the Orogodo River, the Niger Delta was carried out monthly from January to June 2006. Three study stations were selected along the river course (upstream of the cassava impacted site, the cassava-impacted site, and downstream of the cassava impacted site). The study showed that cassava effluents caused a decrease in dissolved oxygen and pH and an increase in biochemical demand (BOD) and nitrates. Significant differences in these parameters were established among the stations sampled. A post hoc test indicated that station II (the cassava impacted site) was the cause of the observed differences. A total of 55 benthic macroinvertebrate taxa with a mean of 6,116 individuals were collected from the three stations along the river. The analysis showed that the overall density of fauna differed significantly among the stations. Cassava effluents permitted the dominance of oligochaetes and dipterans at station II and this resulted in a decline and total elimination of other benthic macroinvertebrates, which are intolerant of the effects of effluents. These preliminary data suggest that the response of benthic macroinvertebrates is important in the study of impacted aquatic systems and that macroinvertebrates have a great capacity to recover from the cassava effluent impact in terms of taxonomic diversity.
Keywords: macroinvertebrates, cassava effluent, Oligochaeta, impact, Niger Delta

Introduction

Most water bodies in Nigeria and to a larger extent in the whole of Africa are subject to an increasing pollution load from the inflow of different kinds of effluents resulting from anthropogenic activities which have become a major threatening factor to the quality of water. Such anthropogenic activities include release or discharge of agricultural waste such as cassava peels, wastewater from agro-allied industries, refineries, human and animal waste, laundering, car washing, wood waste (Walsh *et al*. 2002; Wade *et al*. 2002; Arimoro & Osakwe 2006).

The continuous increase in supply and demand for cassava (*Manihot esculenta* Crantz) in developing countries has accentuated the negative impact cassava production and processing have on the environment and biodiversity (Goodley 2004). Cassava is mostly produced by small-scale farmers on marginal soils and fragile environments in Africa, Asia and Latin America and the Caribbean, where animal manure and chemical fertilizers are not commonly applied to cassava crop (FAO 2004). Extraction of starch from cassava roots requires large amounts of water. After separation of starch and fiber, residual water contains small amounts of starch, proteins and hydrocyanic acid. When this water is released directly into streams and rivers, residual starch can cause rapid growth of bacteria, resulting in oxygen depletion and detrimental effects on aquatic life (Goodley 2004).

Cassava generally contains cyanogens and glycosides that are easily hydrolyzed into hydrogen cyanide (Oti 2002). Toxicological effects of cyanide on organisms have been documented by various authors (Yang *et al*. 1994; Osuntokun 1994; Wade *et al*. 2002; Abiona *et al*. 2005). There are also reports indicating that dissolved hydrocyanic acid resulting from the processing of cassava tubers may lead to death of fish and other aquatic organisms (Okafor 1998; Oti 2002; Oboh & Akindahunsi 2003; Oboh 2004).

Problems of water pollution with cassava effluents are also critical. For example, water bodies receiving untreated cassava water have been reported to be highly acidic, sometimes with pH as low as 2.6 (Zualiya & Muzondo 1993). Suspended solids of effluents may settle on a streambed and spoil fish breeding grounds. These solids are primarily organic in nature; they may decompose and consequently deoxygenate water. Cassava processing related water pollution problems have been reported as serious in many countries, particularly in Thailand (Kiranwanich 1977). As cyanogens glucosides, and Latanstalin are synthesised in tissues of cassava plant, in the course of cassava processing (pressing and washing) cyanide is released into the environment in the form of hydrocyanic acid (Abiona *et al*. 2004). If these products are not properly treated and managed, they constitute a great danger to the environment, especially to the water sources that are used for cassava processing.

Continuous discharge of cassava effluent and associated waste into the aquatic environment and the dearth of information on the response of benthic macroinvertebrates underscore the need for this study. The aims of this study, therefore, are: to determine water quality characteristics and benthic macroinvertebrate communities in the cassava effluent impacted site; and, secondly, to give a comparative account of the same ecological characteristics upstream and downstream of the cassava effluent impacted site, with a view to ameliorating or minimizing effects of this effluent on aquatic organisms.

Material and methods

Description of the study area

The study was carried out in the middle reaches of the Orogodo River in Agbor, Delta State, Nigeria. The Orogodo River lies between the latitude 5°10'–6°20'N and the longitude 6°10'–6°26'E (Fig. 1). The River is principally fed by ground seepage from aquifer in the thick rainforest of Mbiri and, secondarily, by precipitation, municipal effluent and surface runoff from riparian communities. The climate of the area is characterised by the dry and wet season. The wet season lasts from March to October with a short one-month break in August. During the wet season, the river flows more swiftly, its water level rising. Erosion also occurs. The river flows through Agbor, Owa-Ofie Ekuoma-Abavo, Oyoko in Delta State and ends in a swamp between Obazagbon–Nugu and the oil rich town of Oben in Edo State, southern Nigeria. The dry season occurs between October and March. The river substratum consists mainly of fine sand mixed with mud, occasionally with coarse sand and pebbles and decaying debris of macrophytes. The river depth ranges from 2–5 m in the deepest part and 0.38–1.50 m in its shallowest part.

The stream flows across an inhabited area and hence it is affected by different human activities along its channels.

Station I

The station is located about 5 km upstream of station I. Water velocity at this station is low (mean value = 0.14 m/s) when compared to the other stations. The vegetation cover is thick with a dense tunnel of trees,

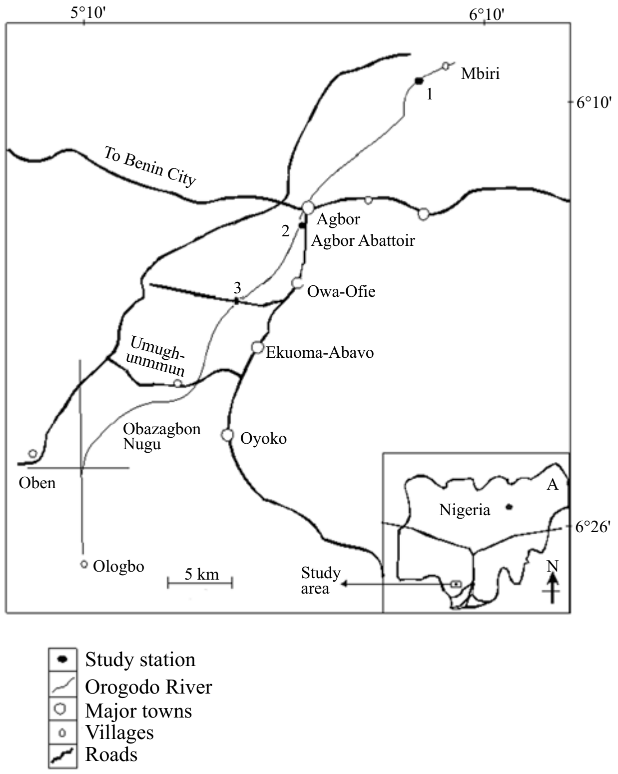

Figure 1. Map of the Orogodo River showing sampling stations (Inset: Map of Nigeria).

and consists mainly of emergent macrophytes namely *Nymphae*, *Lotus*, *Azolla* species; *Utricularia* sp. The streambed is predominantly clay and silt. The marginal vegetation is composed mainly of very tall oil palm (*Elaeis guineenis*), *Raphia vinifera* (P. Beauv.), *Havea brasiliensis* (Muell. Arg.), and *Cocos nucifera* (L.). Human activities at this station include paddling canoes and bathing. Water depth is about 1.48 m and width 3.5 m. Immense human activities are discouraged probably because of its location on the outskirts of the town.

Station II

This station is characterised by the depth, which ranges from 0.27 to 0.79 m and the highest flow velocity. It is surrounded with Elephant grass. The dominant human activity at this station is cassava washing by riparian communities and, consequently, it is the site where effluent from various cassava processing plants is discharged into the stream. No notable fish assemblages are recorded at this station. The riverbed contains cassava debris.

Station III

The station is located 7 km further downstream from station II by the Owa-Ofie village. At this point the riverbed widens considerably. The riparian vegetation of the area could be described as farm bush. Land clearing activities for farming and sand dredging are the predominant forms of land use. For most of its length, the river is flanked by Indian bamboo trees (*Bambusia* sp.) and Palm trees (*Elaeis guineenis*), *Pandanus* sp., and *Mitragyna ciliata*. The current velocity is relatively fast (average value = 0.47 m/s). The substratum is predominantly clay and silt. Human activities include bathing, fishing, sacrificial activities by superstitious believers etc. The water depth is approximately 0.75 metres.

Water Sampling

Water samples were collected monthly from three different sites. Surface water temperatures were taken with a thermometer. Conductivity, pH, total alkalinity, dissolved oxygen, biochemical oxygen demand (BOD_5), and total dissolved solids were determined according to APHA (1985) methods. Other parameters measured included water velocity, which was measured three times by timing a float (average of three trials) as it moved over a distance of 10 m in the middle of the channel (Gordon *et al*. 1994). Depth was measured in the sample area using a calibrated stick. Nitrate-nitrogen (NO_3-N), sulphates, chloride, and phosphate-phosphorus (PO_4-P) were measured spectrophotometrically after reduction with appropriate solutions (APHA 1985).

The substratum composition in each 25 m sampling reach was estimated visually as the percentage of silt, loam and sand as defined by Cummins in Ward (1992).

Macroinvertebrate Sampling

Macroinvertebrate samples were collected by a 3 min kick method with a D-frame net (700–800 µm mesh) along an approximately 25 m long wadable stretch of the river. Four different samples were taken at each sampling site, which covered all different substrata and flow regime zones. This sampling strategy was evaluated (a semi-quantitative sample (0.5 m² quadrat) was collected with a modified kick net (Lazorchak *et al*. 1998) by previous sampling performed prior to the main study and four replicates were established to be good enough to capture the maximum number of different macroinvertebrate taxa. As the substrate was disturbed, the operator and the net moved upstream for the required duration of time. Samples collected from the net were preserved in 10% formalin. In the laboratory, samples were washed in a 500 µm mesh sieve to remove formalin, then macroinvertebrates were picked from the substrate with the aid of an illuminated 10× magnifier, and then the entire sample was enumerated and identified to the lowest practical taxon under a binocular dissecting scope using taxonomic keys and references (Pennak 1978; Durand *et al*. 1981; Merritt & Cummins 1986; Cranston 2000; Gerber & Gabriel 2002; Huxley 2003). The identification of certain dipterans and oligochaete worms, which were prepared on a slide using polyvinylchloride as a mountant, was carried out in the laboratory using an optical microscope.

Community attributes and chemical features of sites were compared using repeated measures ANOVA. Fixed effect ANOVA's were performed using dates as replicates on log (x + 1) transformed data. Significant ANOVAs ($p < 0.05$) were followed by Tukey Honest significant difference (HSD) tests to identify differences between site means. Richness of taxa, diversity and evenness indices were calculated using the computer Basic program SP Divers (Ludwig & Reynolds 1988). Jacquard's index was used for comparing similarities among the stations.

Results

The mean values of some physical and chemical parameters of the study stations are summarised in Table 1. Air temperature, water depth, flow velocity, dissolved oxygen varied spatially and differed significantly ($p < 0.05$) among the stations. The orthogonal comparison using Tukey Honest test showed that station II (the cassava-impacted site) was the cause of the observed differences. BOD, TDS, amounts of sulphates, chloride, nitrates and phosphates were significantly higher at station II as compared with those upstream and downstream of the impacted site. On the other hand, nitrates and phosphates showed wide temporal variations with higher values recorded in dry season months as compared with rainy season months.

The monthly BOD varied among the stations. The BOD value ranged from 0.93 mg/l to 11.8 mg/l. At station II the highest value of BOD (11.8 mg/l) was recorded in June as a result of the low dissolved oxygen value. Meanwhile, at station I the lowest value of BOD (0.93 mg/l) was observed in January. A significant difference was recorded at all the stations ($p < 0.05$). However, a significant difference was noticed not in all months ($p > 0.05$). The monthly pH values varied from 3.62 to 6.80. Station III exhibited the highest pH value in January, while the lowest value (3.62) was recorded at station II in May. A significant difference in pH was recorded not at all the stations and not in all months ($p > 0.05$).

Assemblages of benthic macroinvertebrates

Fifty seven taxa, comprising a total of 6,116 individuals were recorded during the study. Total numbers of taxa and means of individuals found at stations I, II and III were 38 (436), 33 (4,792), and 34 (376) respectively. Station II demonstrated the highest percentage density (78.5%) followed by station I (15.3%). Meanwhile, the density at station III was found to be the lowest (6.2%).

The density of major groups of macroinvertebrates recorded in the entire area (Fig. 2) showed that annelids (Oligochaeta) constituted the largest and the most dominant order accounting for the highest number of individuals. This was closely followed by the orders of Diptera (2,306), Hemiptera (586), Ephemeroptera (289), Crustacea (143), Odonata (102), Arachnida (97), Zygoptera (30), the order of Plecoptera being the least and numbering only 26 individuals. The family Naididae constituted more than half of the total Oligochaeta density. They were preponderant organisms at station II and occurred only sporadically at stations I and III. The *Phylum* mollusca were represented by *Lymnaea*, which were recorded only on a few occasions at station

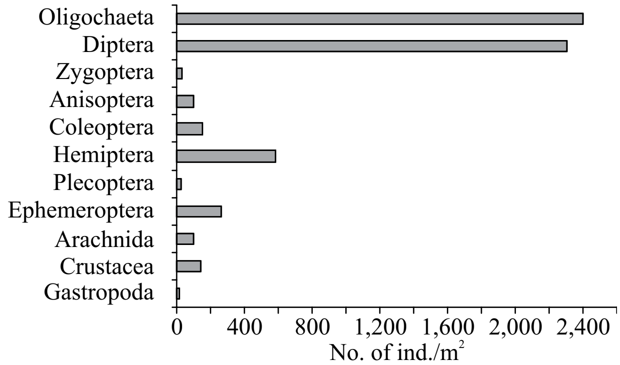

Figure 2. Density of the major groups of macroinvertebrates in the entire study area.

Table 1. Values of some physical and chemical conditions of study stations, January–June, mean ± SE (minimum and maximum parenthesis).

Parameter	Station I	Station II	Station III	$F_{\text{ANOVA monthly variation}}$	Between stations	Probability	
						Months	Stations
Substrate type	Loam	Sand/silt	Silt/loam				
Water depth (m)	0.93 ± 0.22 (0.46–1.60)	0.49 ± 0.09 (0.27–0.79)	0.79 ± 0.02 (0.71–0.82)	2.71	4.01	$p > 0.05$	$p > 0.05$
Air temperature (°C)	28.13 ± 0.39 (27.0–29.0)	29.84 ± 0.46 (28.85–31.90)	30.17 ± 0.84 (28.0–34.0)	2.24	4.73	$p > 0.05$	$p < 0.05$
Water temperature (°C)	26.67 ± 0.401 (25.0–28.0)	25.99 ± 0.43 (24.32–27.40)	27.47 ± 0.46 (26.3–29.1)	0.94	2.86	$p > 0.05$	$p > 0.05$
Flow velocity (m/s)	0.079 ± 0.02 (0.016–0.14)	0.646 ± 0.139 (0.234–1.0631)	0.185 ± 0.0167 (0.12–0.23)	0.58	11.79*	$p > 0.05$	$p < 0.05$
Dissolved oxygen (mg/l)	7.90 ± 0.35 (7.30–9.60)	3.45 ± 0.649 (1.50–6.30)	5.22 ± 0.158 (4.6–5.6)	0.43	21.46*	$p > 0.05$	$p < 0.05$
BOD (mg/l)	2.04 ± 0.39 (0.93–3.03)	7.46 ± 1.81 (3.19–11.80)	3.18 ± 0.17 (2.73–3.90)	2.55	15.14*	$p > 0.05$	$p < 0.05$
pH	5.90 ± 0.31 (4.75–6.71)	5.15 ± 0.389 (3.62–5.93)	6.09 ± 0.288 (1.78–5.02)	0.31	1.75	$p > 0.05$	$p > 0.05$
Nitrate – Nitrogen (mg/l)	0.978 ± 0.475 (0.02–2.57)	1.798 ± 0.352 (0.873–2.89)	1.445 ± 0.385 (0.60–2.63)	64.11*	22.50*	$p < 0.05$	$p < 0.05$
PO_4-P (mg/l)	0.469 ± 0.296 (0.0011–1.73)	0.592 ± 0.217 (0.061–1.12)	0.1412 ± 0.094 (0.012–0.611)	3.62	2.12	$p < 0.05$	$p > 0.05$
TDS (mg/l)	16.96 ± 5.66 (4.44–29.00)	22.89 ± 7.45 (4.63–57.70)	10.67 ± 1.751 (2.95–15.40)	5.56*	3.12	$p < 0.05$	$p > 0.05$
Alkalinity (mg/l)	9.55 ± 3.12 (2.0–24.4)	20.38 ± 3.41 (5.0–27.1)	10.51 ± 2.79 (4.0–23.90)	3.08	6.26*	$p > 0.05$	$p < 0.05$
Chloride (mg/l)	11.61 ± 5.24 (3.01–31.98)	7.76 ± 1.667 (4.73–14.22)	8.81 ± 3.96 (2.01–21.87)	10.89*	1.11	$p < 0.05$	$p > 0.05$
Sulphates (mg/l)	1.978 ± 0.067 (1.75–2.16)	7.98 ± 0.139 (7.40–8.39)	3.57 ± 0.289 (2.87–4.39)	0.88	259.57*	$p > 0.05$	$p < 0.05$

*Note: *indicates significant difference*

I and III. Crustaceans were represented by 3 families with 4 taxa; the family Atyidae comprising *Caridina* sp., the family Desmocariidae comprising *Desmocaris trispinosa*, and the family Palaemonidae comprising *Macrobrachium dux*. These families were restricted to station III.

Arachnidae were represented by four families and four taxa. The family Arrenuridae represented by *Arrenurus* sp., the family Hydrachnellae represented by *Hydrachna* sp., the family Limnocharidae represented by *Piona africana* and the family Argyronectidae which are water spiders and are represented by *Argyroneta aquatica*, were mainly found at station I.

Insects were well represented in the study stretch (Appendix 1). Dipterans followed oligochaetes in diversity and were represented by six taxa. *Chironomus* sp. had the highest number of individuals followed by *Culex* sp., *Cryptochironomus* sp. and lastly *Tanypus* sp. These organisms were recorded in high density at station II, which is the cassava effluent impacted site. Ephemeroptera were represented by two families with six taxa; the family Baetidae comprising *Baetis* sp., *Centroptilium* sp., *Ephemerella* sp., *Cleon* sp. Meanwhile, the family Trichorythidae was represented by *Trychorithus* sp. only. These families were completely absent from station II.

Hemiptera were represented by 10 taxa comprising *Ilyocoris crumicoides*, *Naucoris* sp., *Plecoris femoratus*, *Ranatra limearis*, *Nepa cinera*, *Belostoma* sp., *Lithocerus* sp., *Notonecta* sp., *Gerris lacustris* and *Plea* sp. *Belostoma* sp. was present at all the stations. *Lithocerus* sp. was recorded at station I and II. The presence of *Notonecta* sp. and *Plea* sp. was restricted to station I, while that of others was restricted to stations I and III.

Coleoptera were represented by four families. The family Dystiscidae was represented by *Dysticus marginalis* and *Hydrophilus ovatus*, the family Elmidae was represented by *Promerisia* sp. and *Stenelmis* sp., the family Hydrophilidae was represented by *Hydroporus* sp. and the family Gyrinidae by *Gyrinus marginalis*. Elmidae were mainly recorded at station I, Dysticidae and Gyrinidae being found at all stations. Hydrophilidae were recorded at station I and II.

Odonata were represented by four families and five taxa. The family Libellulidae was represented by *Libellula* sp., the family Gomphidae by *Gomphus* sp., the family Aeschnidae by *Aeschna* sp., the family Coenogridae by *Enallagma* sp. and *Coenagrion* sp. They were found at station I, and at station III they occurred only sporadically. Significant differences were observed among species. The presence of different taxa significantly differed among various stations also.

The spatial and temporal variation in the density of macroinvertebrates at sampling stations of the Orogodo River from January to June 2006 is shown in Fig. 3. The highest mean abundance of organisms (1,182 ind./m²) was recorded in April. The least mean abundance of organisms (785 ind./m²) was observed in June. oligochaetes and dipterans dominated the organism composition throughout all sampling periods. In January, the highest recorded mean density of individuals at station II was

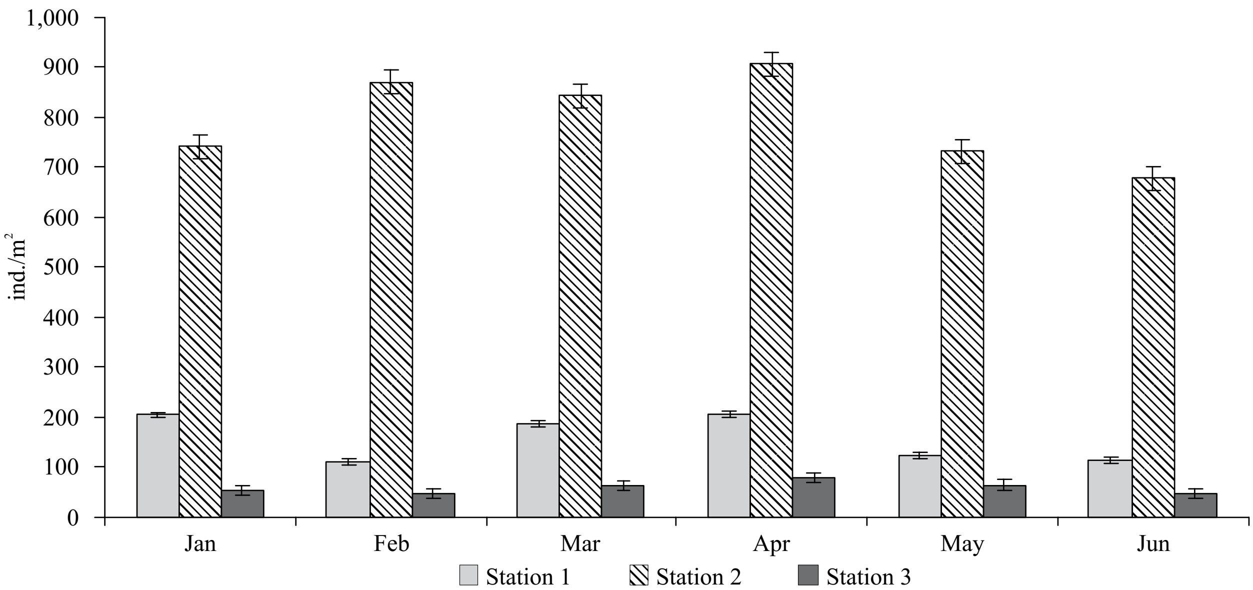

Figure 3. Spatial and temporal variation of macroinvertebrate density.

of 736 ind./m². This figure was close to that recorded at station I, while the density of organisms at station III was only 58 ind./m². The least density of individuals was recorded in June with the highest mean number of 641 ind./m² recorded at station II. This figure was close to that recorded at station I and the least mean density of organisms (44 ind./m²) was found at station III. A significant difference ($p < 0.05$) in the temporal variation in the density of macroinvertebrates was established.

Diversity, evenness and dominance indices of macrobenthic invertebrates at the Orogodo River study stations from January to June 2006 are shown in Table 2. Station III exhibited the highest taxa richness (5.57) closely followed by that at station I (5.41). The lowest taxa richness, diversity, and evenness indices and the highest dominance index (0.092) were recorded at station II. Hutcheson's T-test was used to compare diversity indices among the three stations sampled. The comparison revealed that the difference between Station I and Station II was significant (T_{test} 19.79 > $t_{crit.}$ 3.29). The difference between Station I and Station III was found to be significant (T_{test} 4.596 > $t_{crit.}$3.29) as well. Analysis showed that there was also a significant difference between diversity indices of Station II and III (T_{test} – 5.349 > $t_{crit.}$ 3.29).

Table 2. Diversity, evenness and dominance indices.

	Station I	Station II	Station III
No. of samples	6	6	6
Mean No. of individuals	436	4,792	376
No. of taxa	38	33	34
Taxa richness (Margalef index) (d)	5.41	3.78	5.57
Diversity (Shannon's H)	3.27	2.71	3.00
Evenness (E)	0.90	0.78	0.85
Dominance (Simpson's c)	0.05	0.09	0.07

Faunal similarities

Faunal similarities among sampling stations evaluated by Jacquard's coefficient are given in Table 3. This test showed that the within-pair similarity between stations I and III (0.50) and between stations II and III (0.48) was closer than between other pairs of sampling stations.

Table 3. Jacquard's similarity index.

	Station I	Station II	Station III
Station I		0.33	0.50
Station II			0.48

Discussion

Changes and differences observed in water quality at the stations examined and especially in physical-chemical parameters indicate the abnormality of water at station II due to the impact of cassava effluents.

The surface water temperature was consistently lower than the air temperature in all months. The mean air and water temperature obtained are typical of the African tropical Rivers (Imoobe & Oboh 2003). Higher temperatures were recorded in sunny days than in wet days. This could be attributed to the effect of local climatic conditions during the wet season and shielding from the sun by the shade of vegetation at station I. However, a distinct temporal pattern of temperature variation was observed. The gradual increase in flow velocity, particularly at station II, during the wet season can be attributed to the high flood volume derived from increased precipitation and increased surface run-off and storm water. Changes in water depth (level) were mainly due to successive rainfall throughout all the months. There was a significant difference in water depth at different stations and this can be ascribed to the nature of the riverbed, which is uneven.

This study proved that there is a significant interrelationship between the concentration of dissolved oxygen and the abundance and diversity of benthic organisms because the greatest abundance and species diversity were recorded at station I with the highest dissolved oxygen levels. Impairment of oxygen concentration at station II was attributed to the high content of organic matter. The BOD_5 obtained at station II shows the abnormality of water at this station, which can be ascribed to the cassava wash water impact. The values obtained were significantly higher than those at reference stations (Station I, which is upstream of the cassava-impacted site).

According to BOD, streams are classified into: unpolluted ($BOD_5 < 1.0$ mg/l), moderately polluted (BOD_5 between 2–9 mg/l) and heavily polluted streams ($BOD_5 >$ 10.0 mg/l) (modified from Adakole & Anunne 2003). Station II, at which BOD_5 values were found to be as high as 11.8 mg/l, can be defined as heavily polluted with organic matter. BOD_5 values indicate the extent of organic pollution in aquatic ecosystems, which adversely affects water quality (Jonnalagadda & Mhere 2001). There is a close relationship between the BOD_5 values obtained in this study and those reported for perturbed rivers in Nigeria (Adakole & Annune 2003; Atobatele *et al*. 2005; Arimoro *et al*. 2007).

Although not definitive, pH (hydrogen ion concentration) of an aquatic system is an indicator of water quality and the extent of pollution in a watershed (Jonnalagadda & Mhere 2001). Unpolluted streams normally show a nearneutral or slightly alkaline pH. Water bodies receiving untreated cassava water are usually reported to be highly acidic, sometimes with pH as low as 2.6 (Zualiya & Muzondo 1993). It is possible to state that in May station II, where the recorded pH values were as low as 3.62, is acidic. Meanwhile, pH in most water samples from station I and III approximated 4.75–6.80. Low values of pH at station II could be attributed to the nature of effluents which is acidic (cassava contained hydrocyanic acid).

A total of 55 taxa of macroinvertebrates were reported in this study and this compares fairly well with 43 benthic macroinvertebrate taxa recorded by Ogbeibu and Oribhabor (2002), 46 taxa reported by Edokpayi *et al*. (2000) and 62 taxa reported by Egborge *et al*. (2003) in some perturbed freshwater systems of the Niger Delta. The near restriction of oligochaetes and Diptera to station II can be explained by the discharge of cassava effluents with characteristic properties into sections of the river around the sites. This probably caused disruption of the life cycle, reproductive cycle, food chain, and migrations or imposed physiological stress on less tolerant benthic macroinvertebrates, hence the absence of benthic fauna is associated with clean water. High nutrient enrichment and sedimentation are known to favour oligochaetes at the expense of snails, algal piercing Trichoptera, Ephemeroptera and Plecoptera (Arimoro *et al*. 2007). Again, the high number of individuals recorded at station II could be attributed to the organic substances from cassava effluent whose substrate is mostly covered with bacterial and sewage fungi, which are the main food source for most oligochaetes (Rueda *et al*. 2002).

The overall composition and density of fauna varied both spatially and temporarily in response to physical, chemical and biological factors of the environment. Mollusca were represented by *Limnaea* sp. in a few numbers and were restricted only to station I, while crustaceans were represented by *Caridinia* sp., *Desmocaris* sp. and *Macrobrachium dux*. These were mainly found at station III except, *Macrobrachium dux*, which was found once and was restricted only to station I as it is sensitive to pollution. The complete absence of snails and crustaceans at station II may be due to the effluent of untreated cassava water and the low level of dissolved oxygen at this station.

The calculated taxa richness, Shannon's diversity, and evenness indices revealed the decimating impact of the cassava effluent on communities of benthic macroinvertebrates. Reduced values of these indices and an increased in dominance index at station II are similar to the typical response of benthic communities to organic pollutants (Chindah *et al*. 1999; Walsh *et al*. 2002; Ndaruga *et al*. 2004; Atobatele *et al*. 2005; Arimoro *et al*. 2007)

It is evident from the study that water quality deteriorated as one moved downstream of the Orogodo River basin and this is mainly due to the indiscriminate disposal of effluents of untreated wastewater from cassava washing which is organic waste. Consequently, this has resulted in environmental degradation, which means that only non-sensitive species can survive while sensitive species are prone to extinction. Furthermore, non-sensitive species increased in population density due to the decline of competition with more sensitive species.

The large-scale expansion of cassava processing has created improperly stored waste product in form of peels or fibrous byproducts, which cause a very unpleasant odor, and deplete water resources (FAO 2004). In view of the above, new strategies are needed to balance the current need for food and fodder with the maintenance of the healthy environment for future generations. The impact discussed here is considered preliminary, owing to limitations on the scope and depth of parameters used as criteria.

The impacts of cassava effluents on the Orogodo River must be checked to avoid the extinction of sensitive species, which are already declining in population as this study has pointed out. Furthermore, a more detailed study with more stations upstream and downstream of the cassava effluent impacted sites is necessary to fully document changes in water quality and community structure and the extent and duration of such changes so as to better understand pollution processes in this river that might call for improved regulation and policy development.

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Manijoko nuotekų poveikis bentosinių makrobestuburių bendrijoms Orogodo upėje (Pietų Nigerija)

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Santrauka

Manijoko nuotekų poveikio makrobestuburiams tyrimai Orogodo upėje buvo vykdomi nuo 2006 metų sausio iki liepos kartą per mėnesį. Buvo parinktos trys tyrimo stotys: aukščiau nuo manijoko nuotekų paveiktos vietos, ties manijoko nuotekų vieta ir žemiau manijoko nuotekų paveiktos vietos. Tyrimai parodė, kad manijoko nuotekos sumažina ištirpusio deguonies koncentraciją ir pH, padidina deguonies biocheminį poreikį bei nitratų kiekį. Tarp šių parametrų tirtose stotyse buvo nustatyti patikimi skirtumai. Jų priežastis – manijoko nuotekų poveikis antroje tyrimo stotyje (post hoc testas). Iš viso buvo surinkta 6116 bentosinių makrobestuburių individų, priklausančių 55 taksonams. Bendras bentofaunos tankumas patikimai skyrėsi tarp stočių. Dėl manijoko nuotekų poveikio II stotyje dominavo mažašerės kirmėlės ir dvisparniai, bet sumažėjo arba visai neliko kitų dugno makrobestuburių, netoleruojančių nuotekų poveikio. Šie preliminarūs duomenys rodo, kad pagal dugno makrobestuburių bendrijų pokyčius galima spręsti apie teršalų paveiktas vandens ekosistemas. Išaiškinta, kad šių bendrijų taksonominė įvairovė po manijoko nuotekų poveikio gali atsistatyti.

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Appendix 1. Composition and distribution of macrobenthic invertebrates along the Orogodo River.

Taxa	Station 1	Station 2	Station 3
Annelida			
Oligochaeta			
Lumbriculus variegatus		#	#
Aulophorus furcatus		#	
Brachiodrilus hortensis		#	#
Chaetogaster diatrophus		#	
Chaetogaster limnaei		#	#
Dero limnosa		#	
Dero digitata		#	
Nais communis		#	#
Nais obtuse		#	#
Pristina aequiseta		#	
Stylaria fossularis		#	#
Stylaria lacustris	#		
Hirudinea			
Glossiphiona sp.	#		
Mollusca			
Gastropoda			
Limnaea sp.	#	#	#
Arthropoda			
Crustacea			
Caridina africana	#		#
Caridina gabonensis			#
Democaris trispinosa			#
Macrobrachium dux	#		#
Arachnida			#
Arrenurus sp.	#		#
Hydrachna sp.	#	#	#
Piona africana	#		
Argyroneta aquatica	#		#
Insecta			
Ephemeroptera			
Baetis bicaudatus	#		#
Baetis harrisoni	#		#
Centroptilum sp.	#		#
Ephemerella sp.	#		#
Cleon sp.	#		
Trychorythus	#		#
Plecoptera			
Leuctra sp.	#		#
Neoperla spio	#		
Hemiptera			
Ilyocoris crimicoides	#	#	#
Naucoris sp.	#	#	#
Plecoris femoralis	#	#	
Ranatra linearis	#	#	#

Taxa	Station 1	Station 2	Station 3
Nepa cinera	#	#	#
Belostoma sp.	#	#	#
Lithocerus sp.	#	#	
Notonecta sp.	#	#	#
Gerris lacustris	#	#	#
Coleoptera			
Dystiscus sp.	#	#	#
Promerisia sp.	#		
Stenelmis sp.	#		
Hydrophilus sp.	#	#	
Gyrinus sp.	#	#	#
Odonata (Anisoptera)			
Libellula sp.	#		#
Gomphus sp.	#		
Aeschna sp.	#		
Odonata (Zygoptera)			
Enallagma sp.	#		
Coenagrion sp.	#		
Diptera			
Chironomus transvaensis		#	#
Chironomus fractilobus		#	#
Cryptochironomus sp.		#	#
Culex	#	#	#
Polypedilum bipustulatum	#	#	
Tanytarsus balteatus	#	#	#

 # – indicates the presence of the taxa