Macroinvertebrates As Indicators Of The Water Quality Of An Urbanized Stream, Kaduna Nigeria

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ABSTRACT: A survey was conducted from March to September, 2005 on a fourth order perennial Northern Nigerian stream to evaluate the water quality using the macrobenthic invertebrate community of the bankroot biotope. Physico-chemical variables were determined using standard methods, A total of 1304 macroinvertebrates were recovered. Twenty-seven taxa were recorded. The higher number of taxa (23) was recorded at station 2. The abundance of individuals was highest at station 3. The presence of low densities of pollution tolerant macroinvertebrate groups, the deteriorating water quality and the physco-chemical conditions of the water during the dry season months was a reflection of organic pollution stress caused by decomposing domestic refuse and inorganic fertilizer washed into the stream by irrigation. [Nature and Science. 2008;6(4):1-7]. ISSN: 1545-0740.

KEYWORDS: Macroinvertebrates, water quality, urbanized stream, Kaduna.

INTRODUCTION

Most major cities contain a number of waterways such as bays, harbors and rivers together with a small network of small streams. In Nigeria most of these streams have been subjected to an increasing pollution load from contaminated urban run-off water originating from industrial, agricultural, residential, commercial and recreational areas and institutions such as schools and hospitals (Adakole and Annune, 2003). Ogbogu and Hassan (1996) pointed out the effects of contaminants usually flushed into streams especially in areas of high human activities.

Macroinvertebrate organisms form an integral part of an aquatic environment and are of ecological and economic importance as they maintain various levels of interaction between the community and the environment (Anderson and Sedel, 1979). According to Marques *et. al.* (2003) knowledge of the structure of the benthic macroinvertebrate community provides precise and local information on recent events, which can be seen in their structuring. The use of invertebrates and fish as bioindicators of water quality has been advocated by several researchers (Victor and Ogbeibu, 1985; Ofojekwu *et. al.*, 1996; Edokpayi and Osimen, 2001; Adakole and Annune, 2003).

The Barnawa stream is the main drainage system of most parts of Barnawa, an urban settlement in Kaduna metropolis. Although it is not a major river for fisheries activities because of its size it is the major effluent receiving stream in Barnawa as many gutters are linked to it. It is also used in the irrigation of crops as well as source of drinking water for cattle during the dry season. As a river-let of river Kaduna (Beecroft, 1987) it has a significant contribution to its discharge and consequently its pollution load. The present study examines the effects of various activities associated with urban settlement on some water quality parameters and the macrobenthic invertebrate composition of the Barnawa stream.

MATERIALS AND METHODS

STUDY AREA

The Barnawa stream is located in the southern part of Kaduna Metropolis (Longitude $7^0$50'E and Latitude $10^0$50'N) about 645 meters above sea level. The stream takes its source within the Kalapanzy (Artillery) barracks in Kaduna south and joins other river-lets, which empty into River Kaduna (Mallo, 2001). It is a shallow, fast flowing stream. The area is characterized by flat land surface and easily worked sandy loam soil. The climate of Kaduna is tropical with a distinct rainy season (late April to October) and dry season (October to May) (Beecroft *et. al.*, 1987). The vegetation is guinea savanna, which has been cleared but only relic shrubs of *Isoherlinia doka* and few grasses are still striving.

The major human activity in the catchments area is dry season farming. Heaps of garbage, human excreta and cattle dung were found on slope of the bridge across the stream and these present ugly sites at various spots along the stream. Three sampling stations along a 2.5km stretch were chosen for the study. Station 1 is about 1km from the source. Here the stream is wider than deep. Heaps of refuse were seen by

the sides of the bridge across the stream, with the decomposing refuse emitting foul smell around the catchments area. The vegetation is mainly grasses and creeping plants and there was no farming activity at this station. Station 2 is about 500m from station 1. Human activities here include farming and washing of implements. Bankroot biotope included maize, vegetable crops like spinach, tomato, okra and herbaceous weed. The stream here is relatively wide. Station 3 is about 1km from station 2. The stream
Channel at this site is narrow and fast flowing. Mango trees, grasses and relic shrubs shade this area. The substratum is sandy loam soil. A mechanic workshop and block molding industry are located close to this station; Human activities include washing of block molding implements and motor spare parts.

SAMPLE COLLECTION AND ANALYSIS

Samples were taken at fortnightly intervals over a period of seven months (March – September, 2005) between 0900 hours and 1500hours from the sampling stations, Macrobenthic invertebrate fauna were collected by the kick method (Lenat *et. al.*, 1981; Victor and Ogbeibu, 1985). All invertebrates were killed in the field using small quantities of 40% formaldehyde and later preserved in 70% ethanol for further examination. Further analyses carried out in the laboratory include sieving (mesh size 1.4mm – 250mm), counting and sorting under suitable magnifications (7-40x). The macrobenthic invertebrates were identified using manuals of Pennak (1953); Needham and Needham (1962); Victor and Ogbeibu (1985); Egborge (1995).

Water samples for physico-chemical studies were also collected from stations 1, 2 and 3. Temperature, pH and conductivity were determined in the field using a portable pH/EC/TDS/temperature meter model H1-991301 while dissolved oxygen and Biochemical oxygen demand were determined by titration (APHA, 1985).

Water quality for each station was determined using the diversity (d) indices of Margalef. Magalef's water quality index >3.0 indicates clean condition; values <1.0 indicate severe pollution and intermediate indicate moderate pollution (Lenat *et. al.*, 1981).

All statistical procedures where appropriate were adopted from Zar (1984). SPSS 6.5 applications and Excel (Genstat release 4.03 packages) were used to calculate the two-way analysis of variance (ANOVA).

RESULTS

A summary of the physical and chemical parameters of the study area is given in Table 1. The mean, minimum and maximum values and the standard errors are shown. The water temperature followed closely that of the ambient temperature. Alkaline pH was recorded (pH between 8.5-8.7) during the dry season months. However the pH reduced from neutral to slightly acidic (5.3-7.0) during the rainy season months (July-September). The conductivity was lowest at station 1 and increased downstream. The highest conductivity value (63.0μScm^{-1}), was recorded at station 2. Dissolved oxygen was low during the study period (0.00-3.60mgL^{-1}) while the BOD ranged from 0.00-2.00mgL^{-1}.

The overall macrobenthic invertebrate composition, abundance and distribution in the study stations are summarized in table 2. Twenty-five taxa were identified from a total of 1304 individuals collected. Station 1 had 18 taxa, while stations 2 and 3 had 23 and 15 respectively. Also, station 1 contributed the highest (46.90%) of the total number of individuals and the least number of taxa (15) recorded (Table 2). A summary of the relative contribution of the major invertebrate groups to the overall macrobentthic population at the different stations is presented in Table 3, figure 1 . Station I was dominated by mollusc represented by *Bulinus* and *Biomphalaria* species while dipteran families dominated stations 2 and 3. The variations in taxa and number of individuals between stations were not significantly different (P>0.05). Aquatic insects represented 68.00% of all taxa and 65.97% of all individuals. Coleptera, Diptera, plecoptera and odonata mainly represent them. Three species of Annelida; *Tubifex*, *Nais*, and *Glassiponia* were recorded in all stations, but the fourth species *Stylaria* was absent at station I. Crustacea was poorly represented by a single taxon (Astacidae) in this study. Dipterans were dominated by Chironominae and Tanypodinae families, out of which *Chironomus* was the most abundant. *Simulium*, *Pentaneura and Anopheles* species were restricted to station 2. Two individuals of *Pseudocleon* species poorly represented Ephemeroptera.The indices of general diversity (H), evenness (E) and dominance calculated for the three stations are presented in table 4. Although diversity was higher at station 2 evenness and dominance were higher at station 1 and 3 respectively.

TABLE 1: SUMMARY OF SOME PHYSICAL AND CHEMICAL CONDITIONS OF THE BARNAWA STREAM STUDY STATIONS (March-September, 2002)

	STATIONS								
	1			2			3		
PARAMETERS	**Mean ±SE**	**Min.**	**Max**	**Mean ± SE**	**Min.**	**Max.**	**Mean ± SE**	**Min.**	**Max.**
Air temperature (^{0}C)	**28.5± 1.00**	**26.0**	**32.0**	**27.5 ± 0.8**	**24.0**	**32.0**	**28.0 ± 0.7**	**25.0**	**31.0**
Water Temp. (^{0}C)	**27.5 ±0.72**	**25.0**	**32.0**	**27.4 ±1.00**	**24.0**	**31.8**	**26.5 ± 1.11**	**22.0**	**31.0**
Conductivity (μScm^{-1})	**34.5±2.54**	**32.0**	**39.0**	**52.7±1.11**	**42.0**	**63.0**	**54.3 ± 3.6**	**48.0**	**56.0**
pH	**7.0**	**5.3**	**8.7**	**7.6**	**6.6**	**8.7**	**7.7**	**6.7**	**8.7**
Dissolved oxygen mgL^{-1}	**1.58 ± 0.98**	**0.00**	**3.0**	**1.25 ± 0.62**	**0.00**	**2.1**	**2.50 ± 1.5**	**0.50**	**3.60**
B O D (mgL^{-1})	**1.48 ± 0.28**	**0.00**	**1.68**	**0.67 ± 0.60**	**0.00**	**1.5**	**1.15 ± 0.30**	**1.15**	**2.00**

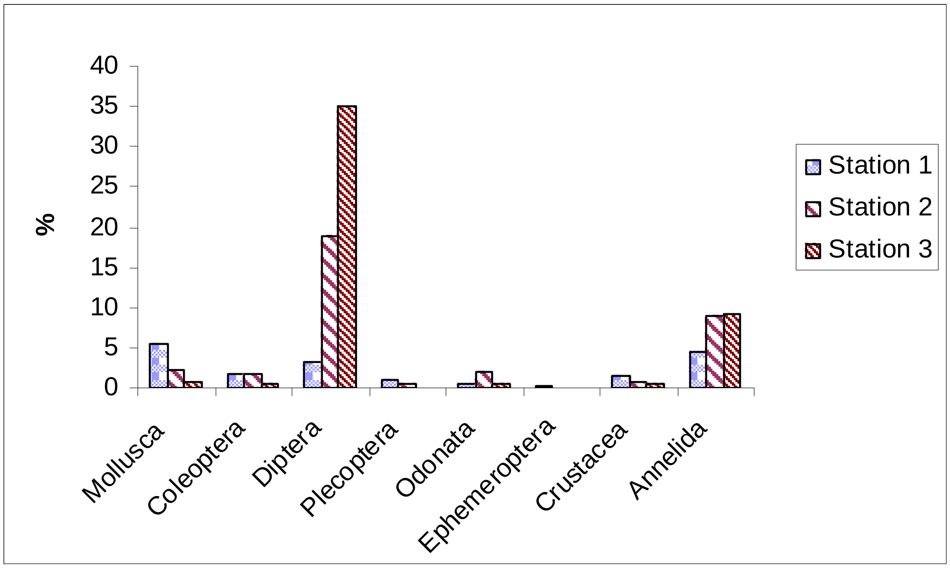

Fig. 1: Relative contribution of the major macro invertebrate groups in the Barnawa stream, March to September, 2005.

TABLE 2: OVERALL ABUNDANCE AND DISTRIBUTION OF MACROBENTHIC INVERTEBRATES AT THE STUDY STATIONS IN BARNAWA STREAM (FEB. TO SEPT., 2005)

	STATIONS			
	1	**2**	**3**	**Total**
MOLLUSCA				
Bulinus spp	12	8	2	22
Biomphalaria	58	12	8	78
Physa spp	-	8	-	8
COLEOPTERA				
Sphaerodema	10	12	2	24
Hydrous sp	2	8	2	12
Phihydrus sp	10	2	4	16
DITERA				
Enstalis larvae	6	16	14	36
Simulium	-	8	-	8
Chironomus	15	143	405	563
Pentaneura	-	40	-	40
Coatate pupa	4	16	18	38
Chronomus pupa	6	21	21	48
Pupa type 1	10	-	-	10
Anopheles larva	-	4	-	4
HEMIPTERA				
Notonecta	-	-	1	1
PLECOPTERA			-	4
Neoperla	2	6	-	8
Brachythermis	12	2	-	14
ODONATA (ZYGOPTERA)				
Coenagrion	-	18	-	18
Aeschna		-	-	-
Pseudagrion	3	3	6	12
Enallagma	-	6	-	6
EPHEMEROPTERA				
(*Pseudocleon)*	2	-	-	2
CRUSTACEA				
Astacidae	20	11	6	37
ANNELIDA POLYCHAETA				
Tubifex	40	10	12	62
Nais	9	24	63	96
Stylaria	-	66	45	111
HIRUDINEA				
Glossiphonia	10	16	4	30
TOTAL	232	460	612	1304
PERCENTAGE	17.8%	35.3%	46.9%	100%

TABLE 3: PERCENTAGE CONTRIBUTION OF MAJOR INVERTEBRATE GROUPS IN THE BARNAWA STREAM, MARCH TO SEPTEMBER 2005. THE VALUES ARE PERCENTAGES; ≥15% DORMINANT; ≥ 5% TO < 15% SUBDOMINANT.

TAXA	STAION1	**STATION2**	**STATION3**	**OVERRALL**
MOLLUSCA	5.37	2.15	0.77	8.29
COLEOPTERA	1.69	1.69	0.61	3.99
DIPTERA	3.14	19.00	35.10	57.24
PLECOPTERA	1.07	0.61	-	1.68
ODONATA	0.38	2.07	0.46	2.91
EPHEMEROPTERA	0.15	-	-	0.15
CRUSTACEA	1.53	0.84	0.46	2.83
ANNELIDA	4.52	8.89	9.20	22.61

TABLE 4: DIVERSITY OF INVERTEBRATES IN THE STUDY STATIONS OF BARNAWA STREAM, MARCH-SEPTEMBER 2005

STATIONS			
	1	**2**	**3**
	n = 14	n = 14	N = 14
No. of Taxa	18	23	15
No. of Individuals	232	460	612
Margalef’s diversity (d)	3.12	3.56	3.24
Evenness (E)	0.173	0.156	0.146
Dominance (D)	0.03	0.12	0.22

DISCUSSION

The physical and chemical properties of the stream showed some variations. However, there was no significant difference between the stations studied. Slight longitudinal variation in water level was observed. The water level of aquatic ecosystem is usually influenced by the rainfall pattern of the drainage basin (Ikusima *et. al.*, 1982). Alkaline pH and low conductivity was recorded in all stations. High pH has been reported for most fluvial (Beecroft *et. al.*, 1987; Emere, 2000; Adakole and Annune, 2003) and Lacustrine ecosystems (Ufodike and Garba, 1992; Kemdirim, 2005) in Northern Nigeria. This may be due to the granite, which forms the basement rock of these water bodies. The low conductivity in this stream places it in class 1 of Talling and Talling’s (1965).

Classification of African waters (the most dilute waters of conductivity < 600 mhoscm^{-1}): this class of water is said to be poor in nutrients.

The low dissolved oxygen concentration recorded agreed with values reported for some Nigerian waters (Ofojekwu *et. al*., 1996; Bukar 2006 unpublished). The dissolved oxygen values revealed anoxic or septic condition during the dry season within the study period. Such low oxygen saturation has been reported in River Kaduna in dry season months when there was little or no flow (Beecroft, 1987; Emere 2000). Low dissolved oxygen has been reported to be deleterious to most aquatic fauna. Based on BOD classification of streams: unpolluted (BOD < 1.0mgL^{-1}), moderately polluted (BOD between 2-9mgL^{-1}) and heavily polluted (BOD > 10mgL^{-1}) (Vowels and Connel, 1980), the stream was moderately polluted during the study period.

The 27 taxa comprising of 1304 individuals recorded was low when compared with over 55 taxa reported for tropical streams (Victor and Ogbeibu, 1985; Edokpayi *et. al.,* 2000; Ogbeibu 2001; Adakole and Annune, 2003). The low species diversity could be due to some physico-chemical conditions like fast flow, high pH, low dissolved oxygen and low conductivity of the water. Odum (1971) had reported that diversity tends to be low in physically controlled systems. These factors probably caused disruption of life cycle, reproductive cycle, food chain and migrations or imposed physiological stress on even the tolerant macroinvertebrates (Adakole and Annune, 2003).

The taxonomic breakdown of the macrointerbrates indicated the dominance of arthropods in species richness followed by mollusc and annelids. *Biomphalaria* was the dominant mollusc. Among the arthropods aquatic beetles (Coleoptera), and dipterans, which include the rattail maggot (*Eristalis*), *Culex* Coatate pupa and *Chironomus* species occurred in all stations. Gaufin (1973) reported that most aquatic beetles can renew their oxygen supply directly from the atmosphere, they are thus unaffected by oxygen depleting wastes while others possess special adaptations for obtaining oxygen (Marques *et. al.*, 2003). All the macroinvertebrates reported in this study during the dry season months belong to the tolerant classes in water bodies, which indicate organic pollution. However, these groups did not show the expected pattern of opportunistic population, that is, few species and large number of individuals (Ogbeibu, 2001; Marques, 2003). This suggests that there maybe other factors, which caused oxygen depletion such as oxidation of iron, accumulation of sediment or inorganic fertilizer from irrigation run-off. Few species of Odonata and Ephemeroptera which are fauna associated with clean water quality were recovered only during the rainy season months. This could be due to dilution during the rains, which caused some improvement in the water quality. The occurrence of stonefly, though low in number was the only sensitive class present during the dry season. Since most species of stoneflies are clean water species (Gaufin, 1973), it is possible that this species occupied in a niche where the oxygen concentration was higher than values recorded for the stream.

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