http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (3): 446-453, 2007
ISSN 1028-8880

Ecology and Abundance of Oligochaetes as Indicators of Organic Pollution in an Urban Stream in Southern Nigeria

[1]Francis O. Arimoro, [1]Robert B. Ikomi and [2]Chukwujindu M.A. Iwegbue
[1]Department of Zoology, Delta State University, P.M.B. 1, Abraka, Nigeria
[2]Department of Chemistry, Delta State University, Abraka, Nigeria

Abstract: A study of the aquatic oligochaetes of an organically polluted segment of an urban stream in Southern Nigeria was carried out to assess the ecological impact of abattoir effluent. Three stations 1, 2 and 3 were selected from upstream of the site receiving abattoir effluent, the impacted site and its down stream, respectively. Among the water quality variables, conductivity, dissolved oxygen, BOD_5, Nitrate-nitrogen, Phosphate-phosphorus and water hardness were significantly different ($p<0.05$) among the stations. Orthogonal comparison using Duncan's multiple range test showed that station 2 (the impacted site) was the cause of the difference. A total of 14 species of oligochaetes were identified with 13 (92.8%) occurring in the impacted station. *Tubifex*, *Dero limnosa* and *Nais communis* were the dominant taxa, less frequent were *Stylaria*, *Aelosoma* and *Lumbriculus variegatus* (Muller). *Pistina* and *Chaetogaster* species were sporadically present. The density of the different taxonomic groups differed among the stations with the impacted station accounting for the greatest abundance and diversity of the organisms. The organic wastes from the abattoir not only altered the water chemistry but also stimulated the abundance of oligochaete worms.

Key words: Water quality, oligochaetes, abattoir effluent, indicator

INTRODUCTION

The urban tracts of rivers represent an example of altered ecosystem where applied research studies are particularly needed for both management and restoration. Monitoring the changes of water quality in streams and rivers can be performed through studies of the organisms living in it (Fenoglio *et al*., 2001). Resident biota in a water body are natural monitors of environmental quality and can reveal the effects of episodic as well as cumulative pollution and habitat alteration (Barbour *et al*., 1996, Rueda *et al*., 2002).

Miserendino and Pizzolon (1999) and Chessman (2003) had earlier classified the families Lumbriculidae, Tubificidae and Naididae (all oligochaetes) as highly pollution intolerant species indicative of poor water quality and were assigned the lowest sensitivity grade in the biotic index of macrobenthic invertebrates.

River Orogodo is a typical urban stream flowing through Agbor town with about 100,000 inhabitants. This stream is the main drainage system of the town accounting for most of the total run off (Ikomi and Owabor, 1997). The river at the middle reaches is subjected to organic pollution arising from effluent from an abattoir. The effluent of this abattoir comprising of the stomach and intestinal contents of slaughtered animals, ashes of burnt animals and blood stains are discharged regularly into the river without any treatment. Also livestock-derived excreta enter the steam either directly or after draining from their watershed.

Detailed distribution and abundance of Oligochaetes is low in the literature. Certain authors (Miserendino and Pizzolon, 1999, 2000; Ndaruga *et al*., 2004; Chessman, 2003) had earlier grouped the oligochaetes into families, perhaps owing to difficulty in identifying them into their respective genus and species. From the fore-going it becomes imperative that a study of the groups of oligochaete worms in an organically polluted stream be presented. Consequently, this study was undertaken to present an account of the water quality status and to identify the groups of oligochaetes to species level that are present in the organically polluted segment of the river. A comparative account of the same ecologically characteristics upstream and downstream of the impacted site will be presented with a view to identifying significant changes in the composition, density and distribution of oligochaetes attributable to this effluent.

MATERIALS AND METHODS

Description of the study area: The Orogodo River is a short stream (about 50 km length) located in Delta state of Nigeria. It lies between latitude 50°.10-6°.20N and longitude 6°.10-6°.26 E (Fig. 1). The stream is fed

Corresponding Author: Chukwujindu M.A. Iwegbue, Department of Chemistry, Delta State University, Abraka, Nigeria
Tel: 90-326-2455845/1309

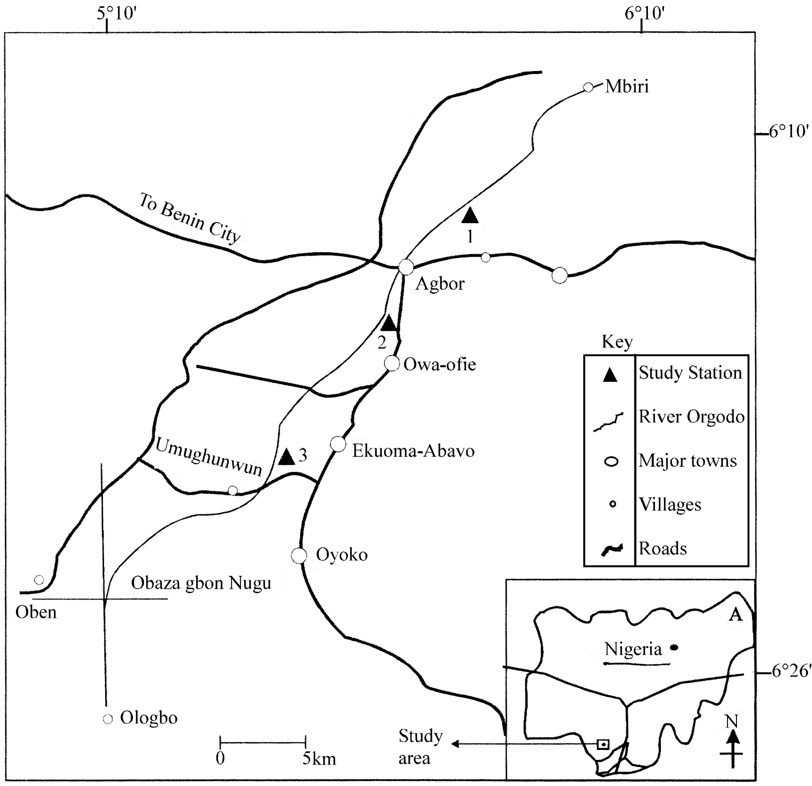

Fig. 1: Map of the study area showing the sampling station (Map of Nigeria showing the location of study)

principally by ground seepage from aquifer in the thick rainforest zone of Mbiri and secondarily by precipitation, municipal effluence and surface run off from the riparian communities. It flows through Agbor main town, Owa-Ofie, Ekuma-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. Samples of Oligochaete worms were collected monthly from July 2003 to June 2004 at three sampling stations, the point of discharge of abattoir effluents, up stream and downstream of this impacted station.

The main features of the stations are described below;

Station 1 is located 15 km from the source. The marginal vegetation consists of few trees shadows, mainly tall oil palm tree, *Elaeis guineensis* and *Cocos nucifera* L., Emergent vegetation namely *Pycreus lanceolatus* Poi and Submerged Vegetation, *Ceratophyllum submersum* L. The streambed is predominantly clay and silt. Human activities here include microartisanal fishery and bathing. The mean water depth is 0.65 m and width 3.5 m.

Station 2 is the impacted station located behind the Agbor town Abattoir. The effluents of the abattoir and livestock-derived excreta including urine and faces are drained directly into the stream here. The nature of the pollutant is described as organic. Some section of the water in this station is conspicuously green with heavy algal growth.

The dominant macrophytes are *Nymphae*, *Lotus*, *Azolla*, *Uticularia* and *Salvinia* sp. Also floating duckweed (*Lemna minor*) are seen close to the river bank. The average water depth is 0.52 m and with 5.8 m.

Station 3 is located downstream of the impacted area, 3 km from the impacted site. The substratum is predominantly clay and silt. It is flanked by Indian bamboo trees (*Bambusa* sp) and palm trees (*Elaeis guineensis*), *Pandanus* sp. and *Mitragyna ciliata*. Human activities here include bathing, fishing, sacrifices by superstitious believers etc. The average water depth is 1.02 m and width 3.7 m.

Water quality analysis: Sampling for water quality parameters and oligochaetes were carried out in the three study stations at monthly intervals between July 2003 and June 2004, covering the dry and rainy seasons. Air and water temperature were recorded with a thermometer, conductivity and pH, were measured using a portable meter. Dissolved Oxygen, Biochemical Oxygen Demand (BOD), total hardness and total alkalinity were measured titrametrically after fixing with the necessary reagents according to methods earlier described by APHA (1985). Other parameters measured included water velocity, determined using the Pin-pong floatation technique. Nitrate-nitrogen (NO_3-N) and Phosphate-phosphorus) (PO_4-P) were measured spectrophotometrically after reduction with appropriate solutions (APHA, 1985).

Sampling for oligochaetes: Sampling for oligochaetes were carried out as described by Pennak (1978). An Ekman grab sampler was used to collect four random samples of the substratum from a cross section of the river bed at each station. The bottom debris was brought into the laboratory and allowed to stand for a few hours until the worms can be seen at the surface of the debris or crawling up the sides of the container. Masses of filamentous algae were washed out with a stream of water. Small species were observed with the aid of dissecting binoculars. Amphibious and large species were picked up by forceps. Most oligochaetes were indentifed to the species level after sorting using published keys, (Macan, 1959; Clegg, 1969; Hynes 1978; Pennak 1978; Hellawell, 1986) with specific reference to the nature of the gill structure, shape, size of the prostomium and nature of the setae (capilliform, serate, sigmoid, hooked bifurcate, pectinate and biuncinate). Oligochaete abundance was obtained by counting all individuals in a taxon and expressing the results as number m^{-2}.

All statistical methods used in analyzing the water quality parameters and oligochaetes community were adapted from Zar (1984) and Magurran (1988). Taxa richness, diversity and evenness indices were calculated using the computer BASIC programme SP DIVERS (Ludwig and Reynolds, 1988). Jaccard's similarity index (Ravera, 2001) was used to compare the sampling locations and to determine which ones were similar in taxa composition and Berger-Parker dominance index (Ravera, 2001) was also evaluated for each sampling station.

RESULTS

Water quality status of River Orogodo: Table 1 summarizes the mean values of the various parameters monitored at the three selected stations over a 12-month time span (July 2003-June 2004) along the river.

Air and water temperatures were in the range of 24-31°C in the three stations sampled and were not significantly different ($p>0.05$).

Mean water depth was also similar in all the stations, except that orthogonal comparison using Duncan's multiple range test revealed that station 3 (downstream) of the impacted site showed considerable high depth 1.20±0.24 m as compared with other stations. Generally water depth was considerably higher in the rainy season than the dry season months.

Current velocity was also not significant among the stations ($p>0.05$). Station 2, however recorded high values of current velocity especially in the rainy season months as a result of the run off of storm water from the town which empties a few kilometers from this station.

Conductivity values were significantly different among the stations sampled ($p<0.05$) the impacted station (station 2) recorded high conductivity values throughout the study period.

Most of the chemical variables, that is dissolved oxygen, BOD_5, Nitrate-nitrogen (NO_3-N), Phosphate-phosphorus (PO_4-P) all measured in mg L^{-1}, were significantly different among the various stations sampled ($p<0.05$). Orthogonal comparison using Duncan's multiple range test showed that station 2 (impacted site) was the cause of the observed differences in these parameters. Total hardness measured in mg L^{-1} $CaCO_3$ was also significantly higher ($p<0.05$) in the impacted station. It had an average of 146±27.24 mg L^{-1} $CaCO_3$ in the impacted station.

Total alkalinity and pH were the only chemical variables that did not vary significantly among the stations; however station 2 recorded higher levels of total alkalinity and pH as compared with other stations sampled.

Aquatic oligochaetes composition, abundance and distribution in the sampling stations: The taxa composition, density and distribution of Oligochaetes in the study area are shown in Table 2. The assemblages fall into five families namely Aelosomatidae, Naididae, Lumbriculidae, Glossoscolecidae and Tubificidae. The distribution of these organisms varied from station 1 (up stream) to downstream as might be expected in view of the different abiotic characteristics of the stations.

Fourteen taxa of aquatic oligochaetes comprising 4, 801 individuals were recorded during the entire study. The total number of taxa and individuals present at upstream (station 1), station 2 and down stream (station 3) were 5 (107), 13 (4,628) and 7 (66), respectively. The most abundant oligochaetes collected from the three stations distributed along the river belong to the following genera, *Tubifex tubifex* (OFM) *Nais communis*

Table 1: Summary of physical and chemical variables of the sampling stations of River Orogodo (mean value±standard error)

Variable	Upstream Station 1	Impacted site Station 2	Downstream Station 3	ANOVA (F-value)	Probability (P)
Air temperature (°C)	26.2±0.32	27.4±0.44	26.4±0.32	1.423	>0.05
Water temperature (°C)	23.6±0.54	24.2±0.61	23.4±0.62	0.841	>0.05
Water depth (m)	0.67±0.12	0.54±0.08	1.20±0.24	2.488	>0.05
Current velocity ($m\ s^{-1}$)	0.36±0.08	0.48±0.09	0.38±0.05	2.620	>0.05
Conductivity ($\mu s\ cm^{-1}$)	121.06±41.66	426.8±96.11	91.02±11.10	21.46*	<0.05
Dissolved oxygen ($mg\ L^{-1}$)	8.78±1.44	3.22±0.97	10.10±0.93	32.12*	<0.05
Biochemical oxygen Demand (BOD)	2.50±0.39	11.24±1.72	2.32±0.36	5.78*	<0.05
Total alkalinity ($mg\ L^{-1}$)	9.24±0.64	11.48±0.55	9.12±0.41	0.89	>0.05
pH	7.4±0.1	7.9±0.4	7.2±0.2	0.46	>0.05
Nitrate-nitrogen ($mg\ L^{-1}$)	0.24±0.06	4.26±0.80	0.28±0.07	29.12*	<0.05
Phosphate-phosphorus ($mg\ L^{-1}$)	0.05±0.01	2.48±0.35	0.14±0.04	31.43*	<0.05
Water hardness ($mg\ L^{-1}$)	78.3±9.32	146.6±7.39	88.4±11.44	37.23*	<0.05

*Indicates significant difference

Table 2: The overall composition and distribution of aquatic oligochaetes in River Orogodo study stations, July 2003-2004 (individuals/m^2)

Aquatic oligochaetes	Stations 1	2	3	(All stations combined) Total
Family Aeolosomatidae				
Aeolosoma variegaturn (VEJD)	-	183	6	189
Family Naididae				
Chaetogaster diatrophus (Gruit)	-	86	-	86
Chaetogaster limnaei (BAER)	-	18	-	18
Nais communis (Piguet)	33	692	19	744
Nais obtusa (Leidy)	-	42	-	42
Dero limnosa (Leidy)	26	924	3	953
Dero digitata (Muller)	-	64	-	64
Aulophorus furcatus (muller)	16	45	-	61
Stylaria lacustris (Leidy)	-	398	11	409
Stylaria fossularis (Leidy)	-	42	-	42
Pistina aequiseta (Bourne)	-	14	-	14
Family Lumbriculidae				
Lumbriculus variegatus (Muller)	23	228	4	255
Family Glossoscolecidae	9	-	16	25
Family Tubificidae				
Tubifex tubifex (OFM)	-	1,892	7	1899
No. of Taxa	5	13	7	14
No. of individuals	107	4,628	66	4,801

Table 3: Percentage distribution in composition of oligochaetes at the study stations

Station	Composition (%)
1	2.23
2	96.40
3	1.37

Table 4: Diversity, richness and dominance indices of oligochaetes in the study stations of River Orogodo

Indices	1 n = 12	2 n = 12	3 n = 12
No. of taxa	5	13	7
No. of individuals	107	4.628	66
Margalef index (S)	0.856	1.422	1.432
Shannon diversity (H)	0.664	0.765	0.767
Maximum possible diversity (H_{max})	0.699	1.114	0.845
Evenness (E)	0.949	0.687	0.908
Berger-parker dominance	0.308	0.409	0.280

(Piguet), *Dero limnosa* (Muller). Less frequent were the genera, *Stylaria*, *Lumbriculus* and *Aeolosoma* with *Aulophorus*, *Dero digtata*, *Chaetogaster*, *Nais obtusa* and *Pistina aequiseta* sporadically present.

Table 5: Jaccard's similarity index between pairs of sampling stations

Stations	1	2	3
1	-	0.29	0.33
2	-	-	0.43

Of all the individuals collected, station 1, 2 and 3 accounted for 2.23, 96.4 and 1.37%, respectively (Table 3). The overall density was significantly different at the three stations (ANOVA, $p<0.05$). An aposteriori test for multiple comparison showed that the density at station 2 was significantly higher than those at station 1 and 3 ($p<0.05$), which were not different from each other ($p>0.05$).

The family Naididae contributed 54% of the total oligochaete density. It was represented by 10 taxa, with *Dero limnosa* (Leidy) occurring as the most dominant taxa, closely followed by *Nais communis* (Piguet) and *Stylaria lacustris* (Leidy). *Chaetogaster diatrophus* (Gruit), *Chaetogaster limnaei* (BAER), *Nais obtusa*

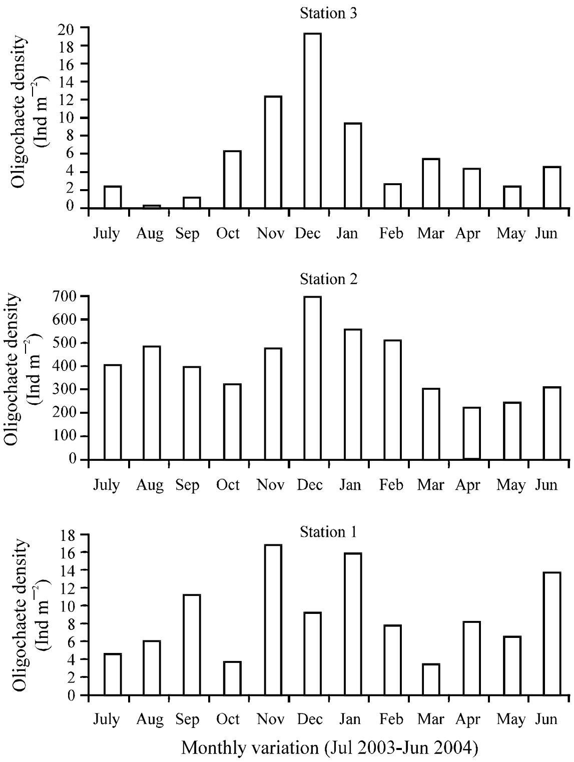

Fig. 2: Spatial-temporal distribution of oligochaetes density in the study stations

(Leidy), *Dero digitata* (Muller), *Stylaria fossularis* (Leidy) and *Pistina aequiseta* (Bourne) were the other representative of Naididae family. They were only found in station 2 (Impacted station) and completely absent in station 1 and 3. Only *Nais communis* (Piguet) and *Dero limnosa* (Muller) were present in all the three stations sampled.

The Family Lumbriculidae was represented by one taxa, *Lumbriculus variegatus* (Muller), contributing 5.1% of the total oligochaete density. It was present in the three stations sampled with the impacted station (station 2) recording the highest abundance (93.1%) of the total *Lumbriculus* density.

Family Glossoscolecidae was represented by one taxon, which was not further identified into genus. This taxon was completely missing in station 2. It was present in few numbers in station 1 and 3.

Aeolosoma variegatum (VEJD) was the only representative taxa of the family Aeolosomatidae. This species contributed 3.94% of the total oligochaete density. It was absent in station 1 and present in station 2 and 3. Station 2 recorded a very high density of this species (96.8%) as compared to the other stations.

Spatial-temporal dynamics in population density: The spatial-temporal distribution in abundance of oligochaetes in the study stations is shown in Fig. 2. In the three stations sampled, the highest densities were recorded during the dry season months, December for station 1 and 3 and November for station 1. In station 1 an overall mean density of 13±4.5 organisms was obtained for the dry season (Nov-Feb.). It was 620±316 organisms and 12±10.6 organisms for station 2 and 3, respectively in the dry season. In the rainy season a mean density of 7±4.0, 269±127 and 3±1.8 organisms were obtained for station 1, 2 and 3, respectively. Analysis of variance revealed that oligochaetes abundance was significant ($p<0.05$) with season.

Diversity, dominance and similarity indices: Table 4 shows the diversity and dominance indices calculated for the three sampling stations. The taxon richness calculated by Margalef index was lowest in station 1 and similar in stations 2 and 3. Shannon diversity (H) was also similar in stations 2 and 3 and lowest in station 1 there was however no statistical significance between the stations ($p>0.05$) sampled. For Evenness, station 1 was more even (0.949), followed by station 3 (0.908) and station 2 recorded the least evenness value (0.687). Berger-Parker's dominance index was highest in station 2 and lowest in station 3. Jaccard's similarity index was used to compare the pairs of sampling stations and the result presented in Table 5. All pairs of sampling stations (that is station 1 and 2, station 1 and 3 and stations 2 and 3) were dissimilar; however station 2 and 3 had the closest similarity (0.43).

DISCUSSION

The water quality changes observed especially the high BOD_5 levels, conductivity, total hardness and low dissolved oxygen values obtained in station 2 portends the abnormality of the water at this station as a result of the impact arising from the untreated abattoir wastes. Nitrate-nitrogen and Phosphate-phosphorus levels of the water obtained from the abattoir discharge station indicate a substantial amount of organic input coming from the abattoir. These values were significantly higher than the levels at the control stations, up stream and downstream of the impacted site. The values of nutrients obtained for this study were very high compared with low titre value reported for similar natural unimpacted stream within southern Nigeria (Ogbeibu and Oribhabor, 2002; Edema *et al*., 2002).

The relatively high velocity reported in station 2, especially during the rainy season months is attributed to surface run off and storm water especially when it rains.

pH of an aquatic system although not definitive is an indicator of the water quality and the extent of pollution in the water shed (Jonnalagadda and Mhere, 2001). Unpolluted streams normally show a near neutral or slightly alkaline pH. Most of the water samples had a pH of about 7 and 8. Station 2 had slightly higher values of pH which again could be traced to the nature of the effluents which is slightly alkaline.

BOD_5 values indicate the extent of organic pollution in aquatic systems, which adversely affect the water quality (Jonnalagadda and Mhere, 2001). In all the water samples BOD_5 was less than 4 mg L^{-1}, except in station 2 where BOD_5 was in the range of 8 to 14 mg L^{-1}, indicating that the effluents from the abattoir was organic in nature thus reflecting high burden of organic pollution.

Water hardness reported for station 1 and 2 were in the range of 62.4-96.45 mg L^{-1} $CaCO_3$, which is in the range of soft water by Lind (1979) classification. Station 2 with an average hardness of 146±7.39 mg L^{-1} $CaCO_3$ is classified as hard water.

The total number of oligochaete taxa reported in this study (14) is high when compared with earlier studies by, Edokpayi *et al.* (2000), Edema *et al.* (2002) and Adakole and Annune (2003) which reported 2, 3 and 5 taxa, respectively in Nigerian freshwater streams. The probable reason for this high number of taxa in this study may be due to the organic materials from the abattoir effluents whose substrate is mostly covered by bacteria and sewage fungi which are the main food source for most oligochaetes (Rueda *et al.*, 2002). Again for most authors they did not classify the oligochaetes to species level. Identification was only given to genera or family level. Related studies elsewhere include those of Misenrendino and Pizzolon (2000) that recorded 7 taxa in a fluvial system in Patagonia and Ogbeibu and Oribhabor (2002) recorded 10 taxa in River Ikpoba, Southern Nigeria. The principal taxa in the present study, *Dero limnosa*, *Nais* sp., *Stylaria* sp. and *Tubifex* sp. have earlier been reported in Nigeria waters (Ogbeibu and Victor, 1989; Edokpayi *et al.*, 2000; Adakole and Annune, 2003; Ikomi *et al.*, 2005).

Station 2 recorded very high abundance of individual oligochaetes as compared to the upstream and downstream stations. The reason for this high density could be that a great majority of oligochaete obtain nutrients by ingesting quantities of the substrate as organic components (Hellawell, 1986) and they are mostly common in the mud and debris substrate of stagnant pools ponds and streams (Mason, 1991), which is the main feature of station 2. Similar studies elsewhere (Solimi *et al.*, 2000, Ravera, 2001; Rueda *et al.*, 2003) revealed that oligochaetes abundance is due to considerable load of organic particles from untreated sewage and livestock effluents.

The overall composition and density of fauna varied both spatially and temporarily in response to physical, chemical and biological factors of the environment.

The dominant family in this study was Naididae with ten representative taxa. It has been proposed by a number of authors (Victor and Dickson, 1985; Ogbeibu and Egborge, 1995; Prygiel *et al.*, 2000), that higher densities of this family in a site is attributed to organic enrichment and abundant masses of filamentous algae. *Nais communis* and *Dero limnosa* showed no habitat restriction.

The family Tubificidae was represented by one genus, *Tubifex tubifex* (OFM). This species was very abundant in station 2 and completely absent in station 1. It occurred only sporadically in station 3. This species has been reported to increase considerably in organic polluted streams (Brinkhurst, 1966) and they possess the ability to thrive in low concentrations of dissolved oxygen (Hellawell, 1986). Tubificids are generally found in sites of high conductivity, fine sand bottom and organic matter enrichment from natural or anthropogenic sources (Miserendino and Pizzolon, 2000), further confirming its high density in the polluted station.

The family Aeolosomatidae was also represented by one genus, *Aeolosoma variegatum* (VEJD) which was dominant in station 2. This species has the ability to migrate easily through out whole drainage systems and forms a resistant mucus cyst that may be easily transported from place to place (Pennak, 1978).

The family Glossoscolecidae was not further identified into genus. This species was the only oligochaete found in the unpolluted segment of the stream. It occurred in few numbers in station 1 and 3. This family included species that are intolerant of pollution and thus could be used as an indicator of good water quality. Adakole and Anunne (2003) also reported the presence of *Glossophonia* sp in relatively unpolluted segments of Bindare stream, in Northern Nigeria.

The density and diversity indices vary both spatially and temporally. The pattern of temporal dynamics in the density of the oligochaetes was also affected by the input of the abattoir wastes. Jaccard similarity index lends more evidence that station 2 density was dissimilar from station 1 and 3, respectively.

Generally, the station receiving wastes from the abattoir (Station 2) showed evidence of environmental degradation, the more sensitive species eliminated, whereas the more resistant ones increase in population density as an effect of the decline of competition with the more sensitive benthic species. Again, the muddy substratum and the relative shallow nature of the stream at this station (impacted site) must have favoured the abundance of these species. Therefore, Oligochaetes do reflect an area with low-oxygen concentration and high enrichment.

REFERENCES

Adakole J.A. and P.A. Anunne, 2003. Benthic Macroinvertebrates as indicators of environmental quality of an urban stream. Zaria, Northern Nigeria. J. Aquatic Sci., 18: 85-92.

APHA (American Public Health Association), 1985. Standard Methods for Examination of Water and Waste Water, 15th Edn., American Public Health Association, Washington DC., pp: 1134.

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenbory, E. Mccarron, J.S. White and M.L. Bastian, 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. J. N. Am. Benthl. Soc., 15: 185-211.

Brinkhurst, R.O., 1966. The Tubificidae (Oligochaeta) of polluted waters. Verh. Int. veren. Theor. An gew. Limnol., 16: 854-859.

Chessman, B.C., 2003. New sensitively grades for Australian river macroinvertebrates. Marine Freshwater Res., 54: 95-103.

Clegg, J., 1969. The Freshwater life of British Isles. Frederick Warne and Co. Ltd., London, pp: 44.

Edema, C.U., J.O. Ayeni and A. Aruoture, 2002. Some observation on the zooplankton and macrobenthos of the Okhuo River, Nigeria. J. Aquatic Sci., 17: 145-149.

Edokpayi, C.A., J.C. Okenye, A.E. Ogbeibu and E.C. Osimen, 2000. The effect of human activities on the macrobenthic invertebrates of Ibiekuma stream, Ekpoma, Nigeria. Biosci. Res. Comm., 12: 79-87.

Fenoglio, S., G. Badino and F. Bona, 2001. Benthic Macroinvertebrate communities as indicators of river environment quality: An experience in Nicaragua rev. Biol. Trop., 50: 1125-1131.

Hellawell, J.M., 1986. Biological Indicators of Freshwater Pollution and Environmental Management. Elsevier New York, pp: 546.

Hynes, H.B.N., 1978. The Biology of Polluted Waters. Liverpool University Press. Cambridge, UK., pp: 202.

Ikomi, R.B. and N. Owabor, 1997. The hydrology of Orogodo River at Agbor. Bull. Sci. Asso. Nig., 12: 167-175.

Ikomi, R.B., F.O. Arimoro and O.K. Odihiran, 2005. Composition, distribution and abundance of macroinvertebretes in the upper reaches of river Ethiope, Delta state, Nigeria. The Zoologist, 4: 68-81.

Jonnalagadda, S.B. and G. Mhere, 2001. Water quality of the odzi river in the eastern highlands of Zimbabwe. Water Res., 35: 2371-2376.

Lind, O.T., 1979. A Handbook of Common Methods of Water Analysis for Limnology. C.V. Moshy Publishers, St. Louis, USA., pp: 69.

Ludwig, J.A. and J.F. Reynolds, 1988. Statistical Ecology. A Primer on Methods and Computing. New York: Wiley/interscience, Wiley, pp: 337.

Macan, T.T., 1959. A Guide to Freshwater Invertebrate Animals. Longman Group Ltd., Expands, pp: 118.

Magurran, A.E., 1988. Ecological Diversity and its Measurement Croom Helm Ltd. London, pp: 176.

Mason, C.F., 1991. Biology of Freshwater Pollution. Longman Scientific Technical, New York, USA., pp: 350.

Miserendino, M.L. and L.A. Pizzolon, 1999. Rapid assessment of river water quality using macroinvetebrates. A family level biotic index for the Patagonia-Andean zone. Acta Limnol. Brasitrensia, 11: 137-148.

Miserendino, M.L. and L.A. Pizzolon, 2000. Macroinvertebrates of a fluvial system in Patagonia: Altitudinal zonation and functional structure. Arch Hydrobiol., 150: 55-83.

Ndaruga, A.M, G.G. Ndiritu, N.M. Grichuki and W.N. Wamicha, 2004. Impact of water quality on the Macroinvertebrate assemblages along a tropical stream in Kenya. Afr. J. Ecol., 42: 208.

Ogbeibu, A.E. and R. Victor, 1989. The effects of road and bridge construction on the bank root macroinvertebrates of a southern Nigeria stream. Environ. Pollu., 56: 85-100.

Ogbeibu, A.E. and A.B.M. Egborge, 1995. Hydrobiological studies of water bodies in the Okomu forest reserve (sanctuary) in southern Nigeria. 1 Distribution and diversity of in vertebrate fauna. Trop. Freshwater Biol., 4: 1-27

Ogbeibu, A.E. and B.J. Oribhabor, 2002. Ecological impact of river impoundment using benthic macroinvertebrates as indicators. Water Res., 36: 2427-2436.

Pennak, R.W., 1978. Freshwater Invertebrates of the United States, John Wiley, New York, pp: 801.

Prygiel, J., A. Rosso-Darmet, M. Lafont Lesniale, A. Durbec and B. Ouddance, 2000. Use of oligochaete communities for assessment of ecotoxicological risk in fine sediment of rivers and canals of the Artois-Picardre water basin (France). Hydrobiologia, 410: 25-30.

Ravera, O., 2001. A comparison between diversity, similarity and biotic indices applied to the Macroinvertebrate community of a small stream: The Ravera River (Como province, Northern Italy). Aquatic Ecol., 33: 97-107.

Rueda, J., A. Camacho, F. Mezquita, R. Hernandez and J.R. Roca, 2002. Effect of episodic and regular sewage discharges on the water chemistry and macroinvertebrate fauna of a Mediterranean stream. Water Air Soil Pollu., 140: 425-444.

Solimi, A.G., A. Ruggiero, M. Anello, A. Mutsch Lechner and G.I. Carchini, 2000. The benthic community structure in mountain ponds affected by livestock watering in nature reserves of central Italy. Proceedings International Association Theor. Applied Limnology, 27: 1-5.

Victor, R. and T. Dickson, 1985. Macrobenthic invertebrates of a perturbed stream in Southern Nigeria. Environ. Pollu. Ser. A., 38: 99-107.

Zar, J.H., 1984. Biostatistical Analysis 2nd Edn. Prentice Hall. New Jersey, pp: 717.