Impact of Urban Effluents on the Macroinvertebrates of a Creek in Accra, Ghana

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Abstract

The impact of effluents on the macroinvertebrate communities of an urban creek in Accra was studied. Five study stations were selected along the reaches of the creek. Water and benthic samples were collected and analyzed between September 2005 and February 2006. The study showed that the effluent discharges caused a significant increase in BOD, COD and NH_3 at the stations that received the effluents. The high levels of total and faecal coliforms at the midstream sections of the creek (626.0 x 10^4 cfu/100 ml and 75.30 x 10^4 cfu/100 ml, respectively) indicated increased pollution levels compared to the reference stations (446.0 × 10^3 cfu/100 ml and 133.0 x 10^3 cfu/100 ml). The Nima Creek showed characteristics of a disturbed urban creek. A total of 19 macroinvertebrate taxa, comprising a total of 11,613 individuals, were collected. Estimated Shannon-Weiner Diversity Index (H′) was low at the midstream section of the creek, H'= 1.14, where the effluents were concentrated than at the upstream H'=1.44 or downstream H'= 1.38 sections of the creek. *Chironomini* and *Physa* were the most abundant taxa within the creek, dominated by the genus *Chironomus,* which is known to be tolerant to pollution, which confirmed the polluted state of the creek. Rigorous and regular assessment and monitoring of effluents from waste treatment plants and other sources that discharge into the creek, with the aim of complying with the Environmental Protection Agency (EPA) guidelines are some of the mitigative measures suggested to protect life in the creek.

Introduction

Freshwater ecosystems represent a major group of habitats around the world (Maitland, 1990). These provide a wide range of habitats for a significant proportion of the world's plants and animal species. Although many are yet to be discovered, it is estimated that the number of freshwater species worldwide is between 9,000 and 25,000 (Cosgrove & Rijsbermann, 2000). This number has been decreasing at an alarming rate due to human impacts such as physical alteration, habitat degradation, excessive water withdrawals and pollution.

In Ghana, as in many developing countries, freshwater resources, unfortunately, have not been efficiently managed. This has resulted in the widespread and high level of pollution in her water bodies, particularly, where they are located near human settlements, industrial (including mining) estates and agricultural undertakings (Water Resources Management, WARM Study, 1998). According to the study, the most significant sources of pollution from human settlements are inadequately treated or untreated human and solid wastes, which are disposed of on lands, in shallow pits and, in some cases, directly into streams. Benthic macroinvertebrates communities play important roles in stream ecosystem functioning and also constitute a critical component in the assessment of stream health. Therefore, a change in the water quality due to the introduction of effluents results in alterations in the benthic community structure, since most macrobenthic species by nature are sensitive to changes in the environment.

In a study of the response of benthic macroinvertebrates to pollution in some developing countries, including Ghana, Thorne & Williams (1997) observed that the macroinvertebrate communities in many developing countries in the tropics displayed similar response to pollution to that observed in temperate areas. Macroinvertebrate studies in Ghana have been primarily concerned with the control of disease vectors, such as *Simulium* and *Bulinus*, and the taxonomy of certain groups of fishes and invertebrates (Hynes, 1974). Other related studies that have been carried out include the annual cycles of macroinvertebrates of the Pawmpawm River in Southern Ghana (Hynes, 1973); the macroinvertebrate fauna of the Ankobra basin (Osafo & Paintsil, 1994) and macroinvertebrate communities in the Odaw stream running through Accra (Thorne *et al*., 2000). Amuzu *et al*. (1995) and Dartey (1999) also assessed the impact of urbanization and microbial populations of the Nima Creek in Accra.

The Nima creek, though not generally used for drinking purposes, is of economic importance to the inhabitants living in its catchment area. The creek, which serves as the main source of water for irrigation for vegetable farmers along its banks also receives effluent discharges from the waste treatment plants of some public buildings. The study, therefore, aimed to assess the impact of these effluents on the quality of the creek's water and the macroinvertebrate communities within the creek.

Materials and methods

Study area

The Nima creek is a tributary of the Odaw river that drains the eastern part of Accra, the capital of Ghana. It has a catchment of about 6.7 km^2 and receives drainage from a 5.2-km^2 urban watershed. It discharges at the Kwame Nkrumah Circle into the Odaw river, which is a major tributary of the Korle lagoon. The creek flows through a flat terrain and the topography is gently rolling except at the headwaters where it is slightly hilly. A large proportion of the basin ranges in elevation from 5.4 to 55.6 m above sea level. It registers its highest point of 60 m along the Dr Amilcar Cabral Road (Airport Residential Area) and has an average slope of 1 in 575 (Oben-Nyarko, 1987). A map of the study area and sampling stations are shown in Fig. 1.

The area falls into the semi-arid coastal savanna zone of Ghana. The ecozone has two rainfall maxima with a mean annual rainfall of about 900 mm. The first rainy season is from April to June, with the heaviest rains in June, whilst the minor rainy season falls between September and October. The dry season, which occurs within the months of January–March, is quite pronounced with mean monthly temperatures of between 26.1 ^{O}C and 27.7 ^{O}C.

The creek flows through an area with two principal land use types. The headwaters of the creek near the Kotoka International Airport are fast urbanising with increase in agricultural and commercial activities as well as residential and office accomodation. The middle sections of the entire creek along the Maamobi-Nima-Mallam Atta townships, however, remain the most heavily urbanized with many residential buildings interspersed with low quality, overcrowded and self-made

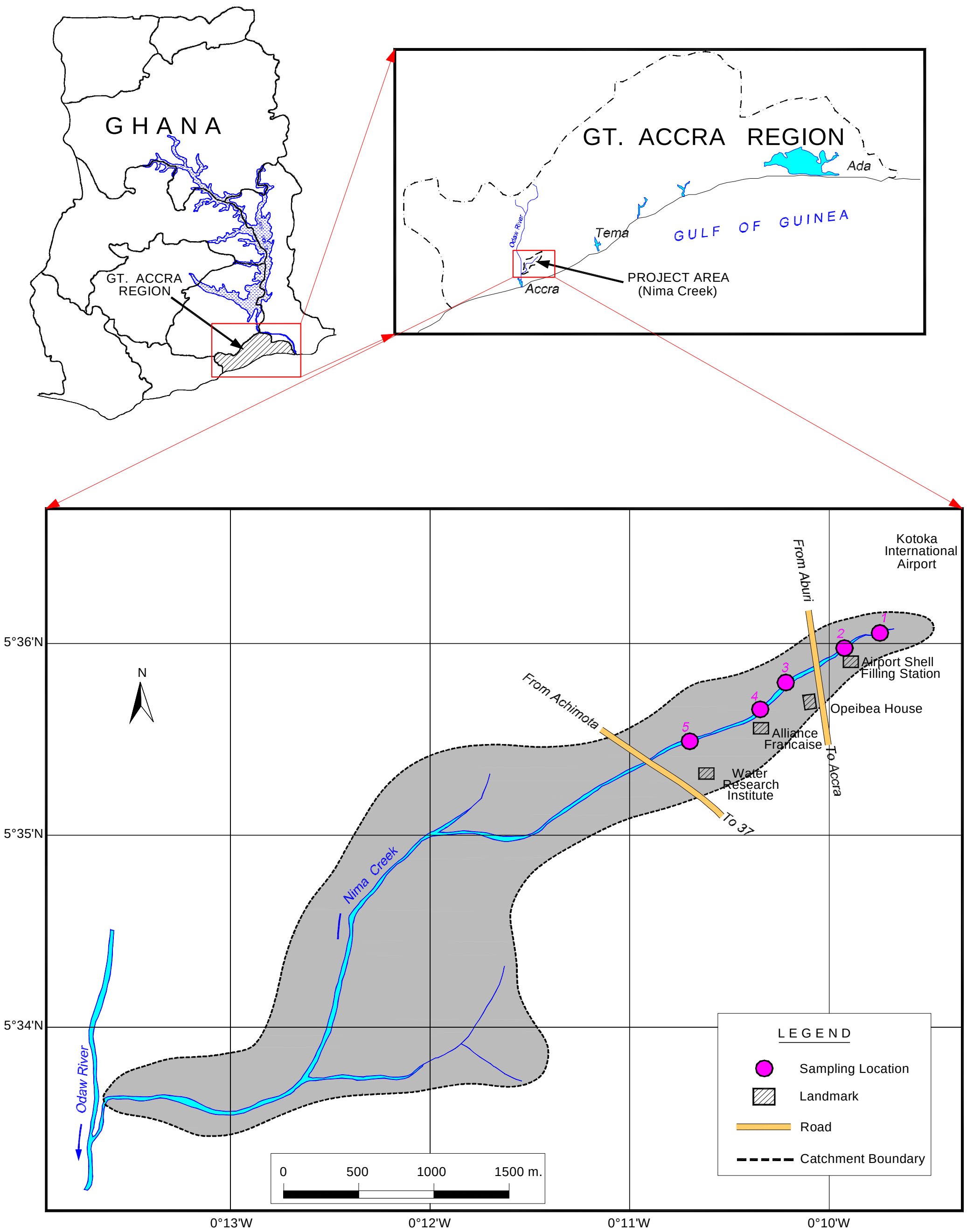

Fig. 1. Map of study area and sampling stations

shelters, which are only marginally served by public utilities. The lower section of the entire creek is also urbanised but not as the middle section. The creek's water flows in a culvert at this section, where it joins the Odaw river (Amuzu *et al*., 1995).

Sampling stations

Five sampling stations were established along stretches of the creek in this study. Two of the stations were located upstream (Zone 1), two in the middle (Zone 2) and one downstream (Zone 3).

Station 1, 05° 36' 14.9" N 0° 10' 30.1" W was located upstream of all known effluent discharges about 300 m away from the Kotoka Airport tarmac. This point was selected to represent the reference station since human activities around this station were minimal. The station also had open fields covered by grass with plantain, palm and mango trees. However, human faeces were observed at the banks of the stream where the water was sampled.

Station 2, 05° 36'13.3" N 0° 10'32.1" W, was located some 50 m downstream the first station and about 10 m from the Airport Shell Filling Station. This station was also chosen to represent one of the unimpacted or upstream stations. The area had a lot of vegetation. Human activities here were also minimal apart from the small vegetable farms. However, human faeces were observed at the banks of the stream where the water was sampled.

Station 3, 05° 35'58.3" N 0°10'50.4" W, was located 50 m from Opeibea House building and 20 m away from the point where the creek received drains from the Opeibea House. This station was chosen to observe and assess the impact of drains from the waste treatment plant of the Kotoka International Airport and the new Airport City in Accra, as well as other unidentified sources on the quality of the creek's water and the macrobenthic community that may be present within the creek. The creek bed consisted of gravel and pebbles with lots of vegetation on banks. The main human activities here were vegetable gardening and commercial car washing. This point was shallow and the flow rate was slow.

Station 4, 05° 35'52.6" N 0° 10'53.1" W), was located behind Alliance Française, about 5 m downstream of effluent discharge from the waste treatment plant of the Golden Tulip Hotel and nearby automobile workshops, as well as runoffs carrying human excreta along the catchment of the creek. Conditions at this station were expected to give an indication of the effects of the discharge from the hotel's treatment plant and other sources on the water quality and the "benthos" of the creek. The main human activities in this area include car washing and vegetable gardening. The banks had gentle slopes with overhanging vegetation.

Station 5, 05° 35'44.4" N 0° 11'09.4" W, was located behind the premises of the CSIR-Water Resources Research Institute, some 200 m away from the point of discharge at Station 4 in the vicinity of a vegetable farm. It was selected to serve as the downstream and a point of comparison from the conditions that prevail at the points of discharge. Human activities here were also minimal except for the temporary building construction works that was ongoing. Impact from human activities was minimal compared to all the other stations. Tall grasses along the banks also obscured that portion of the creek from activities that took place beyond the banks.

Water quality sampling

Water samples for physico-chemical analysis were collected using polyethylene bottles which had thoroughly been washed and cleaned. The water was obtained just about 20 cm below the water surface, kept in an ice chest with ice cubes and sent to the laboratory at the CSIR-Water Research Institute, for analysis. Water samples were stored at below 4 °C until analysed. Horiba digital Water Quality Checker (Model V.10) was used to measure temperature, *p*H, salinity and conductivity on site. This was done by placing probes directly in the water at each station and the measurement for each parameter recorded. Other physico-chemical parameters determined include TDS, turbidity, TSS, BOD, COD, DO, oil, nitrate, nitrite, ammonia and phosphate. SPSS version 11.0 for windows was used to determine the level of correlation, if any, between the physico-chemical and the benthos of the creek.

Bacteriological sampling

Water samples for bacteriological analysis were carefully collected in sterilized glass bottles covered with aluminium foil to avoid contamination. Samples were then stored on ice to slow down metabolic activities of bacteria. Total and faecal coliform bacteria were determined using the membrane filtration (MF) technique (APHA, 1995).

Macroinvertebrate sampling

Five replicate benthic samples were collected at each station using a hand held sweep net of diameter 19.5 cm and a net material with a mesh of 200 µm. Each replicate was collected by taking 10 sweeps of the net from all microhabitats. This method has been found to be an effective means of integrating a range of microhabitats found in the environment (Cheal *et al.*, 1993). Samples were emptied into a 250-ml container on site and preserved with 4% formalin, laced with Rose Bengal to facilitate sorting of macroinvertebrates.

In the laboratory, samples were washed through a 150-µm mesh net to remove debris. The macroinvertebrates retained were poured onto a tray for sorting. The organisms were then examined under a dissecting microscope and identified to the family or genus level, where possible, using identification guides by Dejoux *et al.* (1982) and Pennak (1978). Benthos diversity at the various stations were computed using the Shannon-Wiener Diversity Index (H').

$H' = \sum iP_i (\text{Log}P_i)$ (Clarke & Warwick, 1994).

Results and discussion

Physico-chemical quality of the water of the creek

Water quality data recorded at various stations (zones) between September 2005 and February 2006 throughout the study period are presented in Table 1a. Conductivity, turbidity, total suspended solids (TSS), phosphate and oil varied and differed significantly among the various stations. BOD, COD and NH_3 were significantly higher at the midstream, which constituted the effluent impact stations or zone as compared to those of the upstream and downstream of the impacted stations.

Amuzu *et al.* (1995), in a study on the creek, recorded high BOD levels of (2.5 mg/l–609.0 mg/l) while Dartey (1999) recorded (39.0 mg/l). BOD values for the present study were higher than that observed by Dartey (1999) probably because the level of pollution in the creek had increased. The mean BOD values of 15.3 mg/l, 26.1 mg/l and 13.3 mg/l in zones 1, 2 and 3, respectively, reflect the distributional pattern of organic pollution or discharges along the various sections of the creek (Table 1b). BOD values for Zone 2 (the point of discharge) were comparatively higher than the other stations. The high BOD concentrations in this zone may be as a result of effluent discharges from the waste treatment plants of some public buildings and other faecal materials, as well as household waste, that were found along the banks of these stations. It can, therefore, be inferred that the quality of the water in Zone 3 was better compared to that of Zone 2, and could support a high faunal diversity. The implication of high BOD levels in Zone 2 could mean a reduction in oxygen levels, which eventually affects the aquatic life in the creek.

Amuzu *et al*. (1995), in a previous study on the creek, recorded COD values ranging from 0.0 mg/l to 1566.0 mg/l. COD values in the present study were lower than that observed by Amuzu *et al*. (1995). The comparatively high COD (69.9 mg/l) and BOD (26.1 mg/l) levels observed in Zone 2 was a reflection of the high levels of pollution by organic waste that characterized the stations in this zone.

Dartey (1999), in a study on the creek, recorded a mean ammonia concentration of 9.1 mg/l. Ammonia levels recorded in the present study was higher than that recorded by Dartey (1999). The high levels of ammonia recorded at station OHD 3 and AF 4 in Zone 2 was partly due to the discharge of effluents from the waste treatment plants of some surrounding public buildings. Scattered human excrement, which was

TABLE 1

Comparison of values of physico-chemical parameters measured in the present study with previous studies by Amuzu et al. (1995) and Dartey (1999) and EPA guideline values for aquatic systems

Parameter	*Study*	*Amuzu et al. (1995)*	*Dartey (1999)*	*EPA*
Temperature (^{o}C)	25.9–32.1	24.5–38.0	29.8	–
*p*H (pH unit)	6.4–8.5	6.5–8.5	7.5	6.5 – 8.5
Conductivity (µS/cm)	404.0–1370.0	345.0–2560.0	966.0	–
TDS (mg/l)	247.0–618.0	173.0–1280	-	1000
Turbidity (NTU)	11.5–558.0	–	118.0	5.0
TSS (mg/l)	9.0–800.0	225.0–3900.0	110.0	–
BOD (mg/l)	5.0–54.0	2.5–609.0	39.0	–
COD (mg/l)	17.4–182.0	0.0–1566.0	–	–
DO (mg/l)	0.4–6.1	–	4.6	–
Oil (mg/l)	1.5–9.5	–	–	–
Salinity (mg/l)	0.01–0.06	–	–	–
NO_3 (mg/l)	0 .0 –2.4	–	0.3	10.0
NO_2 (mg/l)	0.0–0.6	–	–	–
NH_3 (mg/l)	1.9–42.9	–	9.1	–
PO_4 (mg/l)	0.4–6.2	–	5.3	–

characteristic of the area, and the use of fertilizer by the vegetable farmers in the area also contributed to the high ammonia levels in the zone (Table 1b). Ammonia is one of the common pollutants found usually in both sewage and industrial effluents (Davies & Day, 1998; World Bank, 1974). The high levels at these stations, therefore, are indicative of a high level of organic pollution. Dartey (1999), in a study of the creek, recorded mean phosphate levels of 5.30 mg/l over the entire study period.

Bacteriological examination of water

The highest total and faecal coliform counts were recorded at the midstream section of the creek (626.0×10^4 cfu/100 ml and 75.30×10^4 cfu/100 ml, respectively), while the lowest counts were observed at the upstream (446.0×10^3 cfu/100 ml and 133.0×10^3 cfu/100 ml) and the downstream (933.0×10^3 cfu/100 ml and 110.0×10^3 cfu/100 ml) (Table 2).

The high levels of the coliforms at the midstream sections of the creek suggest

TABLE 1b

Mean values of key physico-chemical parameters measured at the various zones of the study area

Parameter	*Zone 1*	*Zone 2*	*Zone 3*
Temperature (^{O}C)	26.8	28.9	29.5
*p*H (pH units)	7.4	7.2	7.7
Conductivity (µS/cm)	527.1	704.0	1157.5
TDS (mg/l)	332.0	397.4	600.3
Turbidity (NTU)	159.2	50.1	14.4
TSS (mg/l)	94.2	141.1	216.8
BOD (mg/l)	15.3	26.1	13.3
COD (mg/l)	63.3	69.9	39.2
DO (mg/l)	1.2	2.4	2.2
Oil (mg/l)	4.0	5. 3	2.4
Salinity (mg/l)	0.02	0.03	0.05
Nitrate (mg/l)	0.9	0.7	0.9
Nitrite (mg/l)	0.1	0.1	0.3
Ammonia (mg/l)	6.0	21.6	17.6
Phosphate (mg/l)	3.8	3.7	3.0

TABLE 2

Mean values of key bacteriological parameters measured in the zones of the study area compared with previous study by Dartey (1999) and WHO guideline for bacteriological quality of water

Parameter	*Zone 1 (x 10^3)*	*Zone 2 (x 10^4)*	*Zone 3 (x 10^3)*	*Present study (x 10^4)*	*Dartey (1999) (x 10^3)*	*WHO*
Total coliforms (cfu/100 ml)	446.0	626.0	933.0	1.4×2000	2.4	400.0
Faecal coliforms (cfu/100 ml)	133.0	75.3	110.0	0.0×275.0	590.0	0.0

increased faecal contamination compared to the upstream and downstream sections. This confirmed the fact that the water was not safe for drinking. The high total coliform count observed in Zone 2 may be due to effluents from the waste treatment plants that discharged into the creek. The station was also characterized by scattered human excreta from the inhabitants in the catchment area. This may also be responsible for the high counts observed in the zone. The water, though not used for drinking purposes, served as a source of water for watering vegetables. The high level of ammonia (21.60 mg/l) recorded in this zone confirms the presence of the faecal coliforms since ammonia is a common pollutant associated with sewage and industrial effluents (Davies & Day, 1998; World Bank, 1974).

Macroinvertebrates

Abundance, distribution and percentage composition. The overall taxa composition, distribution and abundance of macroinvertebrates collected during the study period are presented in Table 3a. Nineteen

TABLE 3a

Counts of macroinvertebrate taxa found at each station over the study period

Taxon	*Family/ Species*	*Station* 1	2	3	4	5	*Total*	*%*
Insecta								
Ephemeroptera	Baetidae *Cloeon*	12	82	5	0	134	333	1
Odonata	Libellulidae	10	268	64	1	15	358	2
	Calopterygidae *Phaon iridipennis*	2	93	43	0	434	572	2
Hemiptera	Belostomidae *Diplonychus*	0	1	0	0	29	30	-
	Ranatridae *Ranatra* sp.	0	0	0	0	2	2	-
	Veliidae *Microvelia* sp.	0	0	0	0	2	2	-
	Nepidae *Laccotrephes* sp.	0	0	0	0	1	1	-
Diptera	Chironomini *Chironomus formosipennis*	842	1653	223	65	3738	6521	28
	Chironomini *Polypedilum abyssiae*	134	152	19	0	305	610	3
	Psychodidae	0	11	3	31	1	46	-
Coleoptera	Dytiscidae *Hydraticus exclamationis*	1	0	0	0	243	244	1
	Dytiscidae *Hydrocoptus simplex*	9	26	1	0	7	43	-
	Dytiscidae *Cybister tripunctatus*	0	0	0	0	2	2	-
	Elmidae	0	1	0	0	2	3	-
	Hydrophilidae subfamily Hydrobiinae	0	8	0	0	5	13	-
Total		1110	2295	358	97	4920	8780	
Mollusca	*Lymnaea*	0	13	4	0	15	32	-
	Physa	293	1231	665	13	403	2605	12
	Pleurocera	4	50	19	0	56	129	1
Total		297	1294	688	13	474	2766	
Annelida	Oligochaeta	0	21	0	24	22	67	-
Total		0	21	0	24	22	67	
Total (species)		9	14	10	5	9	19	
Total (individuals)		1407	3610	1046	134	5416	1613	50

macroinvertebrate taxa comprising a total of 11,613 individuals were recorded during the study. The total numbers of taxa and mean number of individuals at the various stations 1, 2, 3, 4 and 5 were 9 (1407), 14 (3610), 10 (1046), 5 (134), and 9 (5416), respectively. The macroinvertebrate taxa present in the creek included Insecta, Mollusca and Annelida.

Insecta were represented by Ephemeroptera, Odonata, Hemiptera, Diptera and Coleoptera. Ephemeroptera was represented by a Baetidae belonging to the genus *Cloeon*. Odonata comprised of the family Libellulidae and Calopterygidae, which was represented by *Phaon iridipennis*. Hemiptera was represented by four families. The family Belostomidae was represented by *Diplonychus,* the family *Ranatridae* was represented by *Ranatra* sp., the family Veliidae was represented by *Microvelia* sp., and the family Nepidae was represented by *Laccotrephes* sp. Diptera was represented by two families. The families comprised of Chironomini and Psychodidae with Chironomini represented by *Chironomus formosipennis and* Chironomini *Polypedilum abyssiae*. Coleoptera was represented by three families, Dytiscidae, Elmidae and Hydrophilidae subfamily Hydrobiinae. The family Dytiscidae was represented by *Hydraticus exclamationis, Hydrocoptus simplex and Cybister tripunctatus*. Mollusca was represented by Lymnaea, *Physa* and Pleurocera. Annelida was represented by Oligochaeta.

Chironomini and *Physa* were the most abundant taxa within the creek. However, it was observed that the genus *Chironomus* predominated the fauna. Station 5 recorded the highest number of Chironomini with a percentage composition of 63% whilst the highest number of *Physa* was recorded at station 3 with a percentage composition of 72%. The percentage composition of the major macroinvertebrate families at the various stations are presented in Fig. 2.

Macroinvertebrate diversity. The benthos diversity among sampling stations estimated using the Shannon-weiner Index (H') are presented in Table 3c. The highest faunal diversity (H'=1.44) was recorded at station 2, representing the upstream of the effluent impacted site. This was followed by station 5, representing the downstream of the effluent impacted zone. The lowest (H'=1.14) was recorded at station 3, representing the midstream or the effluent impacted zone. Thus, station 2 in Zone 1 supported a rich faunal diversity, a situation that was attributed to the fact that it was a reference station and was located above all known discharges. Station 3 in Zone 2 supported a poor diversity, a situation that reflects the impact of the effluents on the benthic communities of the creek.

TABLE 3c

Measure of Shannon diversity (H´) at the various stations over the study area

Station		*H'*
KAC	1	1.16
ASS	2	1.44
OHD	3	1.14
AF	4	1.26
WRI	5	1.38

Conclusion

The variation in water quality observed at the various stations indicated the abnormality of water at the effluent impacted stations (3 and 4) due to the impact of effluents. BOD_5 values indicate the extent of organic pollution in aquatic ecosystems, which adversely affects water quality (Jonnalagadda & Mhere

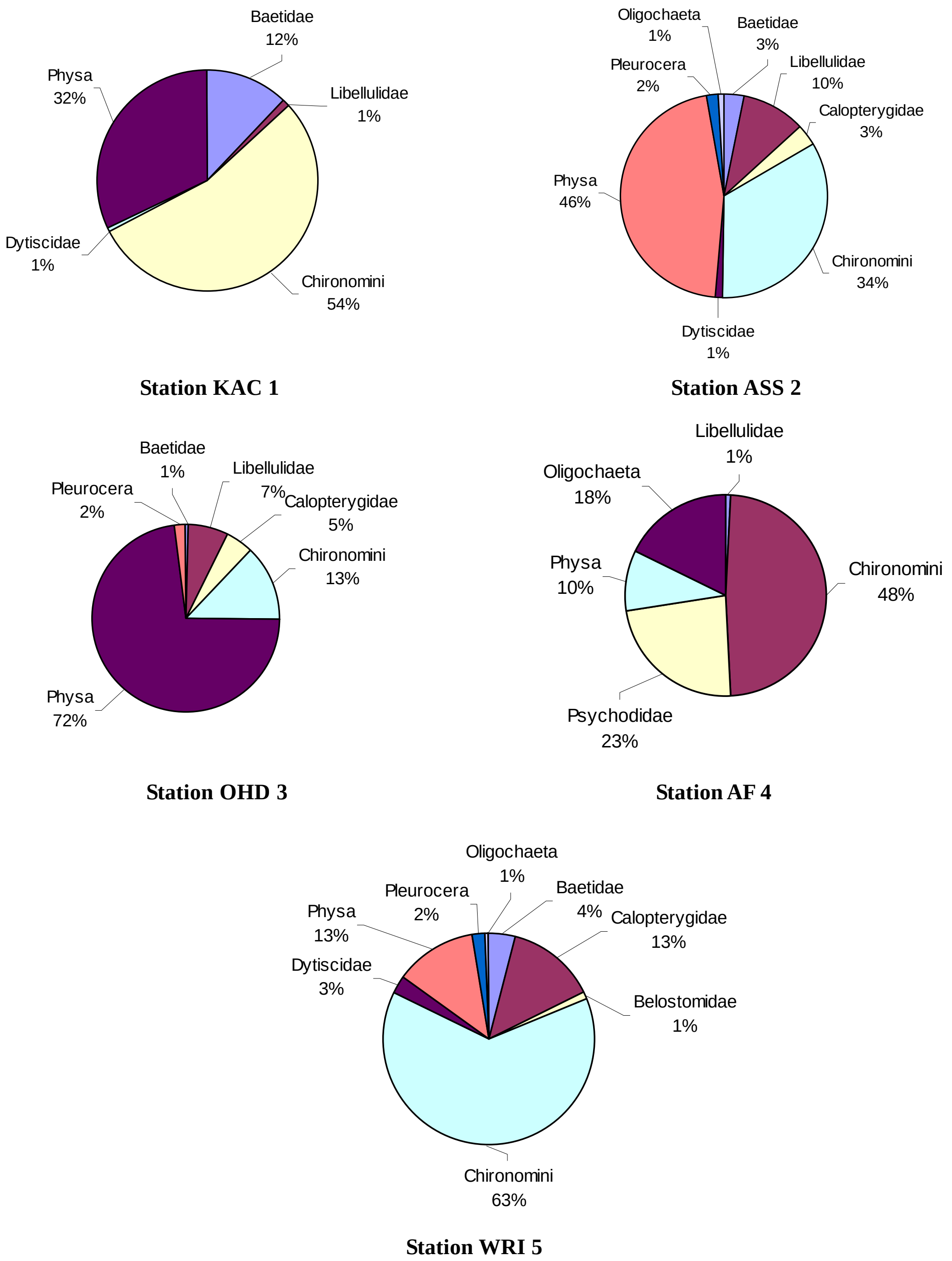

Fig. 2. Major macroinvertebrate families in the fauna at each station

2001). The BOD levels recorded at the various stations, therefore, reflected the distributional pattern of organic pollution along the various sections of the creek. The high COD and NH_3 levels recorded in Zone 2 (effluent impacted stations) compared to the upstream and downstream stations further explained the variation in the water quality of the creek and the high level of organic pollution. The high coliform levels recorded at the midstream stations compared to the reference stations indicated an increased faecal contamination. This poses a serious health threat since the water was used for irrigation purposes.

The macroinvertebrate taxa reported in this study compares fairly well with other macroinvertebrates observed in the Ankobra basin (Osafo & Paintsil, 1994) and the Odaw stream (Thorne *et al*., 2000). The genus *Chironomus*, which is known to be tolerant of organic pollution, predominated the fauna. The high numbers of Chironomini in the creek, therefore, confirmed the polluted state of the creek.

The estimated Shannon diversity indices revealed the impact of the effluent on the benthic communities. The low benthos diversity observed in Zone 2 (representing the effluent impacted stations) compared to the reference stations reflected a disturbed macroinvertebrate community structure and a 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).

A shift from a rich macroinvertebrate fauna at the upstream stations to relatively poor benthos diversity at the midstream stations was observed. The impact of the effluent probably caused a disruption of the life cycle and migration of less tolerant benthic macroinvertebrates resulting in non-sensitive species increasing in population density due to the decline of competition with more sensitive species.

It is apparent from the study that the quality of the creek's water deteriorated as one moved downstream, and this was mainly due to the effluent discharges. This has resulted in the loss of species diversity, a situation that may have adverse effects of the proper functioning of the creek's ecosystem. The impact of effluents on the Nima creek must be monitored to avoid further extinction of sensitive species, which are already declining in population, as this study has pointed out.

Some recommendations suggested include an effective and regular assessment and monitoring of effluents from waste treatment plants before discharging into freshwater bodies by the appropriate regulatory agencies and institutions; enforcement of EIA laws by the EPA, Ghana, on all new developmental projects along the catchment area of the creek, including those that are ongoing as at the time of this study and education of the members of the communities along the creek on the negative impact of their activities on the creek and its effect on the benthos of our freshwaters.

Further studies should be extended to cover other parts of the creek in order 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 creek.

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