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Macrobenthic invertebrates survey and physicochemical parameters of Alaro stream, Oluyole industrial estate, Ibadan

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ABSTRACT
Monitoring qualities of water bodies is necessary to determine how a water body is rated based on its intended use. Macrobenthic invertebrates populations and physicochemical parameters of Alaro stream was investigated to determine its health status. The stream was partitioned into four stations. Water and benthic samples were collected bimonthly from January to June, 2013 from each of the four stations. Benthic sediments were collected using Van-veen grab of 66.6 cm^3 and washed in 0.5mm sieve to extract and record occurrence, diversity and distribution of macro-invertebrates. Species richness, diversity and evenness was determined using Margalef's index, Shannon-Weiner's index and evenness. Benthic analysis was done using Minipal 4 energy dispersive X-ray fluorescence (EDXRF) and flame Atomic Absorption Spectrophotometer (AAS). Water samples were analysed using standard Winkler's titrimetric methods, APHA methods and electrochemical analyser (Consort C933). The relationships between macroinvertebrate population, composition of heavy metals in tissues and physicochemical parameters of water was determined using Pearson Correlation coefficient. A total of seven (7) taxa comprising of 963 individual organisms were recorded. Tubifex species was the most abundant among the macro-invertebrates. Water sample analysis for dissolved oxygen (DO), total dissolved solids (TDS), conductivity and manganese concentration at the four stations, varied significantly ($P<0.05$). There were inverse correlations between Melanoides species and temperature (-0.972), Chironomids and dissolved oxygen (-0.904) had direct correlation with nitrate concentrations (0.944) at $p>0.05$. Rat-tailed maggots showed negative significance with the manganese (insert values) and copper concentrations (insert values) in the sediments. The outcome of the biological and physico-chemical monitoring of Alaro stream suggested that the stream is polluted, hence there is the need for proper domestic wastes and industrial effluent management.

Keywords: Alaro stream, water pollution, benthic macroinvertebrates, Rat-tailed maggots, *Tubifex* species, *Chironomus* larvae

INTRODUCTION
The essence of water to humans can never be over emphasised in its uses in washing, drinking and other activities as farming and production in industries. Water is defined as clear, colourless, odourless and tasteless liquid, that occurs as rain, snow, and ice. It forms, rivers, lakes, and seas.

The aquatic ecosystem is the home for a vast array of diverse organisms from planktonic through pelagic to benthic organisms (Adeogun, 2004). Various nutrients enters the aquatic ecosystems through wastes from different sources, and this results in pollution (Sudhira and

Kumar, 2000; Adeyemo, 2003).

Benthic organisms are effective biomonitors which provide a more accurate understanding of the changing aquatic conditions (Phillips and Rainbow, 1993; Matagi, 1996: Ravera, 1998, 2000; Ikomi *et al*., 2005). These include aquatic larval stage of various insects, worms, aquatic snails, mussels, which are sensitive to changes in water and aquatic ecosystem qualities. Edward and Ugwumba, (2011) reported that the abundance and diversity of benthic organisms is a reflection of the quality of water and its sediments. Popoola and Otalekor (2011) were able to determine the health status of Awba Reservoir, a freshwater body, through the abundance, composition and distribution of aquatic insects and its physico-chemical parameters. The used biological and chemical parameters suggested that the water body was polluted and the continue use of the water may affect the health of humans that depend on the reservoir as source of water. Benthic organisms have poor mobility, while some are completely sessile and possess planktonic and/or pelagic larval or juvenile stages; making them highly vulnerable and susceptible to environmental stress (Ajao and Fagade, 2002). However, metal concentrations in aquatic organisms can provide a more direct way to evaluate the biological impact of trace metals (Phillips and Rainbow, 1993; Luoma, 1996).

Nriagu and Pacyna, (1988) observed from their work that human activities have greatly increased the influxes of many potentially toxic trace metals to aquatic ecosystems. Forstner (1980) reported that the majority of heavy metals such as cadmium, copper, lead and zinc in many impacted environments are derived from anthropogenic sources. About 80% of industrial effluents are discharged daily and virtually untreated into the river through ditches, shallow pits, gutters and trenches (Scheren *et al*., 2002). Sediment-bound pollutants can be taken up by aquatic organisms (Peng *et al*., 2008) because a major fraction of the trace metals introduced into the aquatic environment eventually become associated with the bottom sediments. Environmental degradation by metals can occur in areas where water quality criteria are not exceeded, however organisms in or near the sediments are adversely affected (Gurrieri 1998).

Alaro stream is situated in Oluyole local government area of Ibadan, Southwest, Nigeria. This stream runs through Oluyole industrial estate in Ibadan where it receives a point discharge of industrial effluent. According to Osinbanjo *et al*. (2011) Oluyole industrial estate consists of different industries which include food and beverage processing, organic chemicals manufacturing, basic steel production, agricultural produce production and processing, auto repair workshops, concrete production, pharmaceuticals, agro-allied chemicals and manufacturing company. Effluents from these industries are collected via a network of well-designed drainage system where they are channelled into adjoining rivers. Ipeaiyeda and Onianwa (2011) concluded that only food and beverage industries discharge effluents directly into the stream among many polluting industries located at the estate.

This study was conducted to investigate the physico-chemical parameters of Alaro stream and their effects on the composition, diversity, and distribution of benthic organisms, to be able to evaluate benthic organisms' abundance and the health status of the water.

MATERIALS AND METHODS

Description of study area: The study area was Alaro stream. It lies approximately between longitude $7^{o}20'$N and latitude $3^{o}49'$E and longitude $7^{o}23'$N and latitude $3^{o}51'$E. Alaro stream is situated in Oluyole industrial estate in Oluyole Local Government Area (Figure 1).

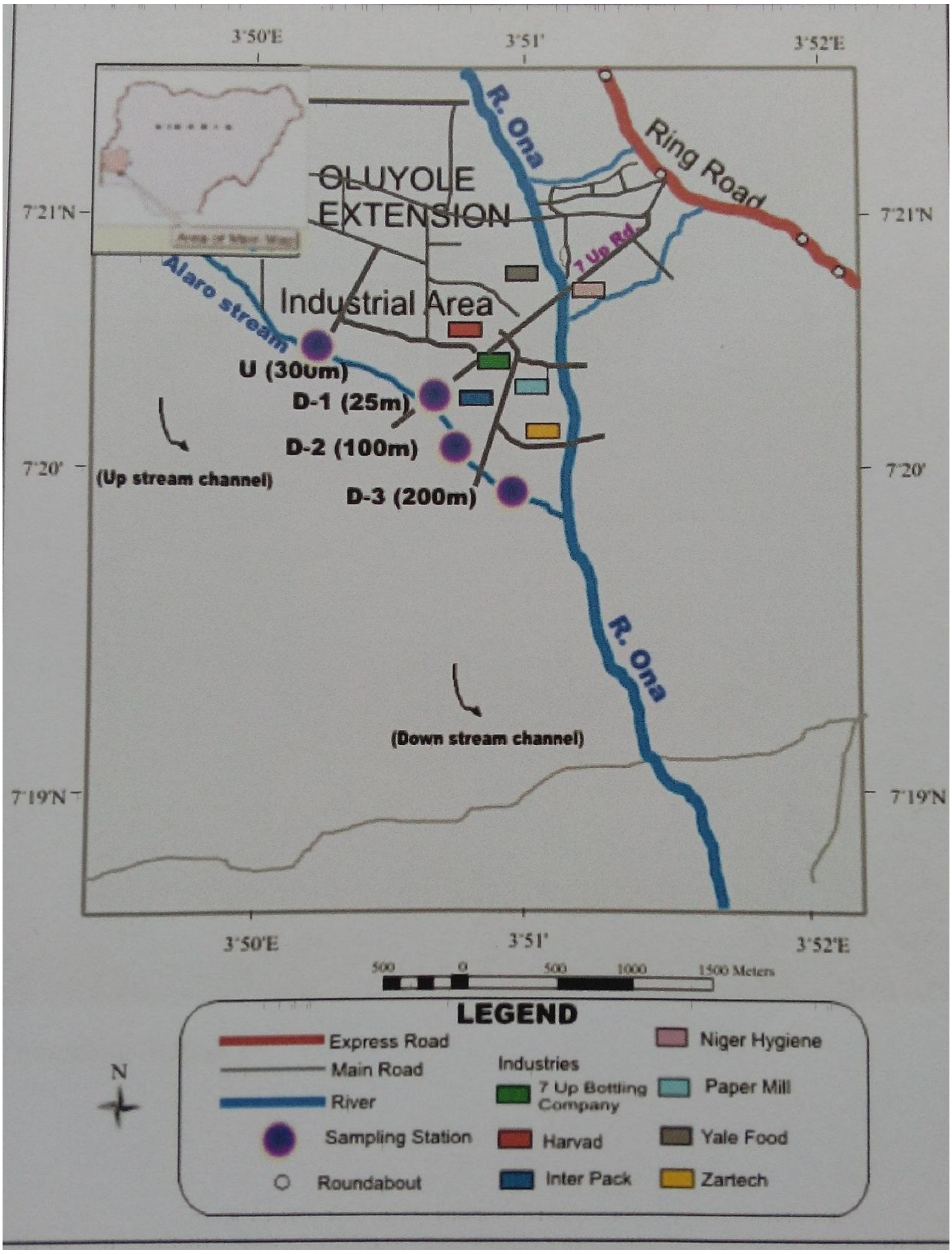

Figure 1: **Alaro stream where samples were collected**

Water sampling and analysis: Water sampling was done fortnightly at four sampling stations along the stream for a period of six months (January – June, 2013) between the cool hours of the morning from 7.00am to 11.00am. Mercury-in-glass thermometer was used to determine the temperature *in situ.* Conductivity, pH, salinity, total dissolved solids (TDS) and ions were determined using Consort C933 electrochemical analyser while the dissolved oxygen (DO) and biological oxygen demand (BOD) were determined by Winkler's titrimetric method as described by APHA (1992) and Ademoriti (1996). Nitrate content was determined by colorimetric method while Vanado-molybdo-phosphoric acid colorimetric method was used to determine phosphate (Ademoriti, 1996).

Benthic sampling, analysis and identification: Benthic sampling was done alongside water sampling. Sediments were collected using Van-veen grab with a surface area of 66.6 cm^3 into appropriately labelled polythene bag with four replicates for onward transmission to the laboratory.

A portion of the sediment samples were air-dried, disaggregated and sieved, using 0.5mm sieve to extract fine particles as described by Salomons and Forstner (1980). The fine dried sediments were wrapped, well-labelled with dates and stored for heavy metal analysis. The metal analysis was then done using Minipal 4 energy dispersive X-ray fluorescence (EDXRF) bench top spectrometer which performs non-destructive analysis of elements from sodium right through to uranium in concentration from 100% down to part per million (ppm) levels.

The remaining sediment samples were poured into a sieve of 0.5 mm mesh size in a water-containing plastic bath. The sediment samples were stirred to facilitate the extraction of the benthic organisms. The extracted benthic organisms were sorted into their respective taxa using identification guides by APHA (1992), WHO (1978) and Miles *et al.,* (1970). The sorted organisms were stored and labelled in sampling bottles preserved by freezing and later oven dried at 105^{o}C for 30 minutes.

The oven-dried samples were grounded to powder and then digested. The resultant solution was then analysed for lead, manganese, iron and copper with a flame Atomic Absorption Spectrophotometer according to the methods of APHA (1992).

Statistical analysis: The data collected were analysed for species richness, diversity and evenness using Margalef's index, Shannon-Weiner's index and evenness respectively.

The species richness was calculated using: d =S-1/logN; and the diversity was calculated using: H = $\sum$ pi log pi. Evenness was estimated using, e= H/log S.

Where; d = Margalef's index

S = number of species belonging to the group

N = total number of organisms in the sample

H = Shannon-wiener's diversity

pi = proportion of the group number to the whole number of the organisms

Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physicochemical parameters of the four sampling stations while Pearson Correlation coefficient (r) was used to determine the interdependence of the parameters.

RESULTS

Physico-chemical quality and heavy metals of the sampled stations: The results of the physico-chemical parameters of Alaro stream are presented in Table 1. Temperature ranged between 25.18 ^{o}C – 31.48 ^{o}C across all the stations. The highest mean temperature was recorded at station 3 (28.70 °C. Conductivity was highest at station 2 and the range was between 312 – 1,044µS/cm; conductivity varied significantly (P<0.05) using ANOVA (Table 1).

The mean variations of pH for the study period indicated that the stream was alkaline with a range value of 6.30 – 11.24. The range values of salinity for the sampling stations was 0.2 – 0.5 while total dissolved solids was 140 – 555 mg/l. Total dissolved solids varied significantly (P<0.05) (Table 1).

The range values of ions, dissolved oxygen and biological oxygen demand were 342 – 2, 240 mg/l, 0 - 3.5 mg/l and 0.6 – 9.4 mg/l, respectively. Dissolved oxygen varied significantly (P<0.05) (Table 1).

The range values of nitrate for the sampling stations were 0.21 – 7.80 mg/l while that of phosphate were 0.07 – 4.14 mg/l (Table 1).

Trace metal analysis

Manganese, iron and copper mean variations for the study period were given in Table 1. Out of the three (3) heavy metals of the sediments, the values of iron were quite high compared to manganese and copper. The iron values were as high as hundreds of mg/g while the manganese and copper were in tens of mg/g. The range values of manganese, iron and copper were 0 – 39 mg/g, 145 – 783 mg/g and 0 – 120 mg/g respectively for the sampling stations. Manganese concentration at the four stations varied significantly ($P<0.05$) using ANOVA

Macro-invertebrate abundance: The composition, distribution and abundance of macro-invertebrates at Alaro stream during the study period was summarised in Table 2.

The benthic organisms encountered during the study were identified and they belong to three (3) phyla and four (4) classes. The phyla were Mollusca, Arthropoda and Annelida. Phylum Annelida had a total of 792 species under class Clitellata. They are the highest encountered organisms during the study period.

Table 1: Mean values and range of physicochemical and heavy metal contents (X±SD) from the four sampling stations along Alaro stream in Oluyole Estate, Ibadan, between January – June, 2013

Physicochemical parameters	Sampled stations along Alaro stream				F-value
	Station 1	Station 2	Station 3	Station 4	
Temperature (^{0}C)	28.36 ± 1.16 (26.67-30.00)	28.39 ± 1.60 (25.18–31.48)	28.70 ± 0.86 (27.39-30.72)	28.05 ± 0.70 (26.48-29.00)	0.67
pH	8.22 ± 0.64 (6.3-8.69)	8.70 ± 1.14 (7.06-11.24)	8.38 ± 1.00 (6.99-10.60)	8.03 ± 0.95 (6.84-10.06)	1.07
Dissolved oxygen (D.O) (mg/l)	1.39 ± 0.92 (0-3.40)	1.06 ± 0.48 (0.45-2.20)	0.88 ± 0.85 (0.40-3.50)	0.51 ± 0.24 (0.20-0.90)	3.45*
Total Dissolved Solids (TDS) (mg/l)	185.67±19.25 (140-210)	275.42±120.72 (190-555)	274.92±98.03 (196-510)	267.25±69.38 (201-451)	3.11*
Ions (mg/l)	1223.25±428 .63 (845-2180)	990.58±285.55 (475-1460)	1026.50±478.90 (345-2240)	981.75±373.21 (342-1710)	0.98
Conductivity (µs/cm)	356.75 ± 24.67 (312-393)	574.92±265.67 (359-1044)	480.67±120.94 (368-816)	501.83±129.75 (377-849)	3.85*
Salinity	0.20 ± 2.90 (0.20)	0.28 ± 0.12 (0.20-0.5)	0.24 ± 0.07 (0.20-0.4)	0.25 ± 0.07 (0.20-0.4)	1.96
B.O.D (mg/l)	0.58 ± 0.84 (-0.60-2.40)	1.50 ± 2.70 (0.10-9.40)	1.12 ± 1.33 (0.25-5.00)	0.81 ± 1.06 (0.08-3.40)	0.70
Nitrates (mg/l)	1.92 ± 0.69 (0.92-3.10)	1.93 ± 1.15 (0.30-4.31)	2.07 ± 1.73 (0.38-5.16)	2.26 ± 2.67 (0.21-7.80)	0.10
Phosphates (mg/l)	1.14 ± 0.64 (0.07-2.03)	1.43 ± 0.57 (0.37-2.11)	1.56 ± 0.79 (0.37-3.12)	1.77 ± 1.25 (0.37-4.14)	1.13
Manganese (Mn)	18.92 ± 5.65 (13-33)	17.83 ± 8.40 (6-39)	12.17 ± 4.59 (6-20)	14.83 ± 5.22 (0-19)	2.96*
Iron (Fe)	256.58 ± 72.84 (156-390)	307.08±157.12 (209-783)	307.25 ± 58.43 (172-377)	255.5 ± 65.26 (145-354)	1.11
Copper (Cu)	20.08 ± 16.02 (0-44)	26.83 ± 32.69 (0-120)	9.42 ± 14.72 (0-37)	19.08 ± 20.33 (0-47)	1.26

Mollusca had the second highest species encountered which belong to 2 classes. A total of 123 individuals were recorded from the class Gastropod and one from class Bivalvia. Phylum Arthropoda had a total of 47 individuals from class Insecta. A grand total of 963 benthic organisms were sampled across all the stations within

Table 2: **Benthic organisms' composition, abundance and distribution from the sampled stations along Alaro stream in Oluyole Estate, Ibadan, between January and June, 2013.**

					MEAN ± SE STATION 1 (Months)						MEAN ± SE STATION 2 (Months)			
Phylum	Class	Genera/Species	JAN	FEB	MAR	APRIL	MAY	JUNE	JAN	FEB	MARCH	APRIL	MAY	JUNE
Mollusca	Gastropoda	*Bulinus sp.*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
		Physa sp.	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.50 ±0.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
		Melanoidessp.	1.50 ±1.50	5.00 ±3.00	2.00 ±1.00	1.00 ±1.00	0.50 ±0.50	3.00 ±2.00	6.00 ±2.00	0.00 ±0.00	2.00 ±0.00	2.50 ±2.50	1.50 ±0.50	0.00 ±0.00
	Bivalvia	*SphaeriumSp*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
Arthropoda	Insecta	Rat-tailed maggot *EristalisSp*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
		ChironomousSp	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	1.00 ±1.00	1.00 ±1.00	0.00 ±0.00
Annelida	Clitellata	*TubiexSp*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	16.50 ±16.50	25.50 ±23.0	1.50 ±0.50	3.50 ±0.50
					STATION 3 (Months						**STATION 4 (Months)**			
Phylum	Class	Genera/Species	JAN	FEB	MARCH	APRIL	MAY	JUNE	JAN	FEB	MARCH	APRIL	MAY	JUNE
Mollusca	Gastropoda	*Bulinussp.*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
		Physa sp.	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.50 ±0.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	1.00 ±0.00
		Melanoidessp.	1.00 ±1.00	3.00 ±3.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	4.50 ±3.50	7.00 ±0.00	3.50 ±2.50	2.00 ±2.00	2.00 ±1.00	11.00 ±6.00
	Bivalvia	*SphaeriumSp*	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.50 ±0.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
Arthropoda	Insecta	*Rat-tailed maggot Eristalis Sp*	0.00 ±0.00	1.50 ±1.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.50 ±0.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
		Chironomous Sp	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	3.00 ±3.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	16.50 ±15.5 0	0.00 ±0.00
Annelida	Clitellata	*TubiexSp*	1.00 ±1.00	4.50 ±4.50	47.50 ±47.50	56.00 ±0.00	129.0 ±30.0	84.00 ±61.00	0.00 ±0.00	1.50 ±1.50	10.00 ±10.00	1.50 ±1.50	1.00 ±1.00	13.00 ±10.00

a sampling period of 6 months. Station 3 had the highest population of 663 and station 1 had the lowest population with 27 benthic organisms (Table 1)

The species richness and diversity of macro-invertebrates collected in the sampled stations were summarized in Table 4. Station 4 had the highest species richness with Margalef's index value of 1.838 followed by station 3 (1.772), station 2 (1.435) and lowest at station 1 (0.699). Shannon's index was highest at station 4 (0.503) and lowest at station 1 (0.069). Evenness's index was similarly highest at station 4 (0.720) and the lowest evenness value was recorded at station 3 (0.094).

Benthic organisms' composition, distribution and abundance.

Benthic organisms' composition in Alaro stream as shown in table 2 revealed that Melanoides was the most abundance in all the stations, however, all other organisms were either found in one station or the other in a very small population. In the month of June both stations 1 and 4 recorded highest values of Melanoides (3.00±2.00) and (11.00±6.00) respectively. Stations 2 and 3 had highest mean values of (6.00 ±2.00) and (3.00±3.00)for January and February respectively.

Mean values of benthic composition in Station 1 had lowest species diversity but was also evenly distributed. Pearson correlation coefficient values (r) between the means of the metals in *Melanoides* sp, sediments and physic-chemical properties were summarised in Table 3. There were significant correlation (1.000) between conductivity and salinity (p=0.01). As the copper concentration in *Melanoides* sp increased, the conductivity and salinity increased. The lead concentration in *Melanoides* sp inversely correlated with dissolved oxygen (D.O) and positively correlated with phosphates ($p<0.05$). It was also observed that as D.O increased, the phosphate decreased ($r = 0.993$) ($p<0.01$), TDS was also decreasing as ions increased.

Table 3. Pearson's Correlation Coefficient Values (r) between the Means of Metals in *Melanoides* species, Metals in Sediment and Physicochemical Properties

	Heavy metal in *Melanoides* species tissues				Heavy Metals in Benthic Sediment			Physicochemical Properties in Sediment									
	Mn	Fe	Cu	Pb	Mn	Fe	Cu	Temp	pH	DO	TDS	Ions	Conductivity	Salinity	BOD	Nitrates	Phosphates
Mn Tissue	1																
Fe Tissue	.298	1															
Cu tissue	-.766	.061	1														
Pb Tissue	-.844	-.222	.352	1													
Mn	.725	.723	-.147	-.831	1												
Fe	-.494	-.665	.600	.037	-.348	1											
Cu	.210	.803	.412	-.472	.825	-.119	1										
Temp	-.009	-.902	-.088	-.200	-.360	.743	-.532	1									
Ph	-.145	-.250	.593	-.401	.203	.845	.377	.529	1								
DO	.840	-.004	-.456	-970*	.675	.051	.251	.402	.392	1							
TDS	.980*	-.322	.852	.723	-.643	.634	-.115	.104	.337	-.723	1						
Ions	.973*	.106	-.877	-.757	.547	-.465	-.023	.128	-.225	.807	-.973*	1					
Conductivity	-.833	-.015	.993**	.446	-.258	.616	.310	-.056	.547	-.531	.906	-.922	1				
Salinity	-.828	.001	.995**	.441	-.246	.606	.323	-.070	.543	-.530	.900	-.920	1.000**	1			
BOD	-.612	-.269	.887	.094	-.148	.886	.269	.355	.867	-.118	.756	-.680	.877	.874	1		
Nitrates	-.618	.060	.129	.927	-.638	-.339	-.375	-.484	-.684	-.939	.453	-.553	.209	.209	-.229	1	.
Phosphates	-.896	-.079	.520	.976*	-.720	.065	-.273	-.311	-.298	-.993**	.794	-.857	.597	.595	.217	.900	1

*. Correlation is significant at p= 0.05 level (2-tailed) . **. Correlation is significant at p= 0.01 level (2-tailed).

Table 4 has the species richness values for the four stations. Pearson correlation coefficients values (r) between the means of the physicochemical properties and benthic macro-invertebrates encountered during the sampling period at Alaro stream was also summarised in Table 5. There was inverse correlation (-0.972) between *Melanoides* species and temperature at $p<0.05$. As pH increased there was a decrease in the population of *Physa* species. It can also be observed that chironomids correlated inversely (-0.904) with dissolved oxygen and directly (0.944) with nitrate concentrations. Rat-tailed maggots showed negative significance with the manganese and copper concentrations in the sediments.

Melanoides sp decreases steadily in manganese concentration from station 1(0.31 mg/g) to station 4(0.018 mg/g). It also showed a steady increase of lead from station 1(0.014 mg/g) to station 4(0.027 mg/g). Copper had the highest value in station 2(0.007 mg/g) and the lowest at station 1(0.003 mg/g) while station 3 and 4 had similar copper content of 0.005 mg/g. Iron showed the highest concentration of all the metals at station 4(0.45 mg/g) followed by station 1(0.43 mg/g), station 2 (0.42 mg/g) and station 3 (0.28 mg/g).

Table 4: Species richness, diversity and other indices of benthic organisms in the four sampled sites at Alaro stream

Statistical Analyses	Station 1	Station 2	Station 3	Station 4
No. of taxa (S)	2	4	6	5
No of individuals (N)	27	123	663	150
Margalef's index (d)	0.699	1.435	1.772	1.838
Shannon's index (H)	0.069	0.293	0.073	0.503
Evenness's index (e)	0.229	0.487	0.094	0.720

Table 5: Pearson correlation coefficient values (r) between the means of the physico-chemical properties and benthic macro-invertebrates encountered during the sampling period at Alaro stream.

Parameters	*Bulinus* sp	*Physa* sp	*Melanoides* sp	*Sphaerium* sp	*Eritalis* sp	*Chironomids* sp	*Tubifex* sp
Temperature	0.035	-0.522	-0.972*	0.814	0.575	-0.730	0.806
pH	0.865	-0.965*	-0.635	0.107	-0.137	-0.642	0.187
D.O.	0.186	-0.616	-0.587	-0.143	-0.442	-0.904*	-0.199
TDS	0.376	-0.076	0.026	0.369	0.480	0.399	0.478
Ions	-0.381	-0.031	-0.249	-0.171	-0.334	-0.560	-0.282
Conductivity	0.709	-0.329	0.094	0.016	0.077	0.285	0.143
Salinity	0.713	-0.327	0.106	-0.050	0.062	0.290	0.128
B.O.D	0.833	-0.707	-0.369	0.195	0.093	-0.204	0.311
Nitrates	-0.488	0.850	0.676	0.111	0.435	0.944*	0.124
Phosphates	-0.126	0.537	0.500	0.217	0.495	0.849	0.280
Mn (Sediments)	0.414	-0.402	0.133	-0.824	-0.959*	-0.374	-0.842
Fe (Sediments)	0.575	-0.713	-0.723	0.579	0.406	-0.455	0.659
Cu (Sediments)	0.742	-0.441	0.344	-0.877	-0.923*	-0.053	-0.824

DISCUSSION

This study was conducted within the period of six months which include both wet and dry period, consequently the effects of period in question impacted on the different parameters. Physico-chemical parameters variation may be due to the period of sampling which were late dry and early rainy periods. This was similar to the report of Akin-Oriola (2003) who reported wide variations in some physico-chemical properties such as dissolved oxygen content, conductivity and pH. It may also be due to the domestic, agricultural, industrial effluents and waste discharged into the stream, Adeyemo *et al.* (2008).The observed temperature ranges between 25^{o}C and 32^{o}C these falls within the surface water temperature reported by Ajibade *et al.,* 2008 while studying the water quality in the major rivers of Kainji Lake. According to Ayodele and Ajani (1999), 21^{o}C to 32^{o}C is the recommended temperature for aquatic life in tropical environment such as Nigeria. The variations in temperature may be as a result of industrial activities in the estate where the stream is located. Dissolved oxygen is important as a respiratory gas, and it is used in biological and chemical reactions. The DO content in this study ranged between 0 – 3.5 mg/l which was low. These low DO values recorded during the study could be associated with the various anthropogenic activities that occur in and around the stream which included domestic wastes dumping, run-off of organic wastes from the nearby farmlands and burning of wood shavings among others. According to Yakub (2004), low DO concentrations in Awba stream was attributed to human activities. The dissolve oxygen content and phosphates shows negative correlation (-0.99) in this study. The source of nitrates and phosphates in the water body was the raw sewage channelled into it (Aggarwal *et al.,* 2000; Adeyemo, 2003). Increased sewage content of a stream, increases the microbial activities in the stream thereby decreasing the dissolved oxygen content with increased phosphate level (insert references to support this statement). The metal concentrations in sediments and, *Melanoides* species (bioindicator), varied greatly. According to Adeyemo *et al.* (2008), pollutants are conserved in the sediments over long periods according to the chemical persistence and sources of contaminants. The differences in the concentrations of metals in the bioindicator and the sediments may be due to the rate of bioaccumulation and duration of exposure of the organisms to the contaminants. It may also be as a result of movement of organisms from one point to the other. Tyokumbur and Okorie (2013) reported that the freshwater snail *M. tuberculata* was capable of bio-concentrating trace metals in its tissues and that the potential for bio-concentration is strongly dependent on the amount of trace metals in the sediments and the regulatory capacity of the snail. Benthic macro-invertebrates tolerate pollution at different level of occurrence. The pollution tolerant species are able to survive water with low dissolved oxygen. In this study, pollution tolerant species such as *Tubifex* species showed high abundance compared to other species. Chironomids correlated inversely (-0.90) with dissolved oxygen. This is similar to the report on Macroinverbrates as indicators of the water quality of an urbanized stream in Kaduna, Nigeria (Emere and Nasiru, 2007). The number of benthic macro-invertebrate taxa observed was low during this study. Edward and Ugwumba (2011) attributed low taxa number of macro-invertebrate fauna composition of Egbe reservoir to the usual characteristics of tropical waters. This may be due to some physico-chemical conditions of water like high pH and low dissolved oxygen content observed during this study. Wang *et al.* (2002) reported that aquatic organisms are affected by pH because most of their metabolic activities are pH dependent. The pH range observed during the study period is higher than the 6.5 – 8.2 range reported by Murdock *et al.* (2001) as the optimal pH range for sustainable aquatic life. Nitrates correlated positively with Chironomids. This may be attributed to the organic wastes discharged into the stream. The stream had low salinity during the study period which is an attribute of freshwater bodies (Boyd, 1979).

The Margalef's index (d) values at the four stations were all less than three (3). Margalef's index greater than 3 indicates clean conditions (Lenat *et al*., 1980). This suggests that the pollution status of Alaro stream is high. The presence and occurrence of *Tubifex* species and *Chironomus* species larvae at stations 1, 2 and 3 is indicative of an opportunistic occurrence as they are known to occur at low dissolved oxygen.

It may be concluded that biological and the physico-chemical procedure of monitoring freshwater are interrelated. Also, occurrence, abundance and distribution of benthic macro-invertebrates depend on the physic-chemical properties of the stream. The freshwater snail, *M. tuberculata*, is a useful bio indicator of trace metal pollution in an aquatic ecosystem. It was found at all the sampling stations making it useful for bio-monitoring. It is therefore recommended that proper wastes disposal habit be cultivated by the industries and every household around the stream. This may be achieved through proper sensitisation. The responsibility of waste management should not be left for the government alone as the health impact is felt by all.

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