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Some Aspects of the Physicochemistry and Heavy Metal Content of Water, Sediment and *Cynothrissa mento* (Regan, 1917) from Badagry Creek, Lagos, Nigeria

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ABSTRACT

Some physicochemical parameters and heavy metal content of water, sediment and *Cynothrissa mento* from Badagry Creek were studied for eight months (July, 2010-October, 2010; January, 2011-April, 2011) spanning wet and dry seasons. The heavy metals investigated are Cu, Zn, Cd, Pb, Fe and Cr while the physicochemical parameters are temperature, pH, conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), salinity, turbidity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), alkalinity and hardness. All the physicochemical parameters except temperature and dissolved oxygen exhibited significant ($p<0.05$) monthly variation. However, six of the physicochemical parameters (total suspended solids, turbidity, biological oxygen demand, chemical oxygen demand, alkalinity and hardness) representing 50% showed significant ($p<0.05$) seasonal variation. All the heavy metals studied except Cr showed significant ($p<0.05$) monthly variation in at least one of the environmental compartments (water column, sediment and *Cynothrissa mento*). The range of concentrations of the six heavy metals in *Cynothrissa mento* are Cu (0.06±0.02-0.91±0.19 mg kg^{-1}), Zn (0.19±0.04-1.69±0.33 mg kg^{-1}), Cd (0.01±0.01-0.05±0.02 mg kg^{-1}), Pb (0.01±0.01-0.12±0.01 mg kg^{-1}), Fe (4.33±0.43-16.88±1.32 mg kg^{-1}) and Cr (0.01±0.01-0.05±0.02 mg kg^{-1}). Most of the values of the physicochemical parameters and heavy metals were within the limits recommended by World Health Organisation, Nigeria's Federal Environmental Protection Agency and United States Environmental Protection Agency except alkalinity, hardness and Fe in sediment. This study shows that the water quality variables of Badagry Creek can sustain fish and the heavy metal content is not harmful to fish and man yet.

Key words: Water quality variables, *Cynothrissa mento*, Badagry Creek, heavy metal, seasonal dynamics, recommended limits

INTRODUCTION

The biotic component of the aquatic ecosystem which consist of fauna and flora are indispensable economic resources. Major components of aquatic fauna are the fin fish and shellfish (shrimps, prawns, crabs, lobsters, calms, scallops, periwinkles, oysters etc). Rural artisans who depend on fisheries as a means of livelihood concentrate on shallow water bodies like rivers, creeks, lakes, lagoons, etc for their fishing expedition. This is due to their inability to explore larger water bodies because of limited capital. In Nigeria, artisanal fisheries sector produces bulk of fish consumed by the populace. In addition, the fisheries sector provides income, employment, raw materials and foreign exchange to the Nigerian populace and the nation (Kumolu-Johnson, 2004). However, in recent times, Nigerian inland water bodies have been subjected to various forms of degradation due to pollution arising from domestic wastes, industrial effluent, agricultural run-offs, oil spillage, mine effluents and obnoxious fishing practices (Ndimele, 2008). The result is that the associated fishery, the biota and the ecosystem upon which fishers depend for a living are destroyed. Consumption of fish caught from water bodies so polluted also poses severe danger to the consumers (Kumolu-Johnson *et al*., 2005). One of such pollutants is heavy metals.

Heavy metals are pollutants that have been a source of concern for aquatic ecologists. This is because most heavy metals are non-biodegradable. Once they enter the system of a biota, they persist there and bioaccumulate along the food chain (Ndimele *et al*., 2009). Some may combine with substances within the aquatic environment to yield even more toxic products like the production of methyl mercury from mercuric compounds. Some heavy metals like copper, manganese and zinc play important roles in the metabolic activities of organisms. Others like cadmium, arsenic and mercury have no metabolic roles and are toxic even at very low concentrations (Abduljaleel and Shuhaimi-Othman, 2011; Taweel *et al*., 2012). Copper and chromium are essentials micronutrient for animals and plants. In humans, copper helps in the production of blood haemoglobin while in plants, it is important in seed production, disease resistance and regulation of water. Copper is used as an effective algaecide and molluscicide (Abou-Zaid *et al*., 1988). Cadmium is produced as an inevitable by-product of zinc and occasionally in lead refining. Cadmium is chemically similar to zinc, an essential micronutrient for plants, animals and humans. Cadmium is used in the production of nickel/cadmium batteries, as rechargeable or secondary power sources. This battery has high output, long life, low maintenance need and high tolerance to physical and electrical stress (Fishar and Ali, 2005).

Iron is the most abundant metal in the earth crust and is believed to be the tenth most abundant element in the universe. Iron is essential to all organisms, except for a few bacteria. Excess iron in the body causes liver and kidney damage, medically referred to as haemochromatosis. Some iron compounds could be carcinogenic (Gambrell, 1994). Chromium is used in metal alloys and pigments for paints, cement, paper, rubber and other materials. It has also been found to be an effective anti-fouling component. Zinc is essential in the synthesis of nucleic acid and it is also a component of many enzymes. Zinc and compounds derived from it are used in medicine, paint and plumbing works (Clarke *et al*., 1981).

Aquatic biota has been used to monitor heavy metal pollution in aquatic ecosystems for decades (Etesin and Benson, 2007; Kamaruzzaman *et al*., 2011). The choice of biota depends on several factors like heavy metal accumulating potential of the organism, motility, economic value etc. However, fin fish and shellfish are often the preferred biota because of their big size which makes them easily identifiable and their ability to accumulate heavy metals (Ghosh *et al*., 2006; Ndimele *et al*., 2011a). *Cynothrissa mento*, the Nigerian fangtooth pellonuline is a clupeid of economic and nutritional importance in Nigeria but has not been adequately studied. The first study on *C. mento* was by Kumolu-Johnson *et al*. (2010) and it investigated the heavy metal content of the fish from Ologe Lagoon, Lagos, Nigeria. The second study on the fish was on the comparative morphometric characterisation of *Cynothrissa mento* from Ologe, Badagry and Epe Lagoons, Lagos, Nigeria (Ndimele and Kumolu-Johnson, 2011). This study is a continuation of the series on the study of *C. mento* from Nigerian aquatic ecosystems. Specifically, this study investigates the physicochemical and heavy metal contents of *C. mento* from Badagry Creek.

MATERIALS AND METHODS

The location of Lagos state in Nigeria: Lagos state is situated in the southern part of Nigeria and can easily be identified as a result of its coastal location and physical environment. Lagos state lies between longitudes 20°42'E to 30°42'E and latitudes 60°22'N to 60°42'N. The state is bounded in the west by Republic of Benin, in the east and north by Ogun state while in the south, it is bounded by the Atlantic Ocean (Kumolu-Johnson *et al*., 2005).

The climate of Lagos state: Lagos state has a high temperature range (23-30°C) and the highest occurs around November-December and February-March. These periods fall in the dry season. The lowest temperature is recorded in the peak of the first rainy season. The climate is characterised by a double maxima type of rainfall which normally lasts from April to November. Sometimes, the rain could start early, around March or even February and could also end late, encroaching into November and occasionally December. During this time, the rainfall is always heavy with some occasional flooding especially in coastal areas. The intensity of the rainfall is as a result of coastal location, low elevation and the prevailing rain bearing south westerlies. The rainfall is at its peak around May-July and September-October with a short break in August (mean: 1600 mm; range: 1007-2000 mm) (Kumolu-Johnson, 2004). The relative humidity is high throughout the year and ranges between 65-80%. Lagos state climate is the West-Equatorial type due to its position to the equator and also the Gulf of Guinea.

Description of study area: Badagry Creek (Fig. 1) lies between latitudes 6°22'N and 6°42'N and longitudes 2°42'E and 3°42'E (Agboola *et al*., 2008). Badagry Creek empties directly into Ologe Lagoon which is also in Lagos state, Nigeria. The area is inhabited by fishers who depend on the resources of the water body for livelihood. There are no industries in Badagry but the on-going expansion of the Badagry road that leads to Republic of Benin may change this in few years' time.

Methodology: This study was conducted for a period of eight months (July-October 2010 and January- April 2011). Composite samples were collected monthly from four sampling sites. Data were generated on a monthly basis from these sites with respect to various physicochemical parameters and heavy metal content of Badagry Creek.

Physicochemical parameters: This study was conducted for a period of eight months (July-October 2010 and January-April 2011). Composite water samples were collected from the four sampling stations of Badagry Creek from July, 2010 to April, 2011 for analyses of physicochemical parameters. The water samples were collected in 1 L plastic containers. Immediately after collection, the water samples were stored in a cooler in order to ensure that the physicochemical properties of the water remain intact. Temperature and pH were determined *in situ* by a mercury-in-glass thermometer and a pH meter (Metrohm Herisau E520), respectively. The water turbidity was measured using nephelometer (Analite portable nephelometer Model 156, Mcvan Instrument, Mulgrave). Dissolved oxygen, salinity, alkalinity and total hardness were determined by titration (Boyd, 1981). Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) were determined according to the methods described by APHA (1985).

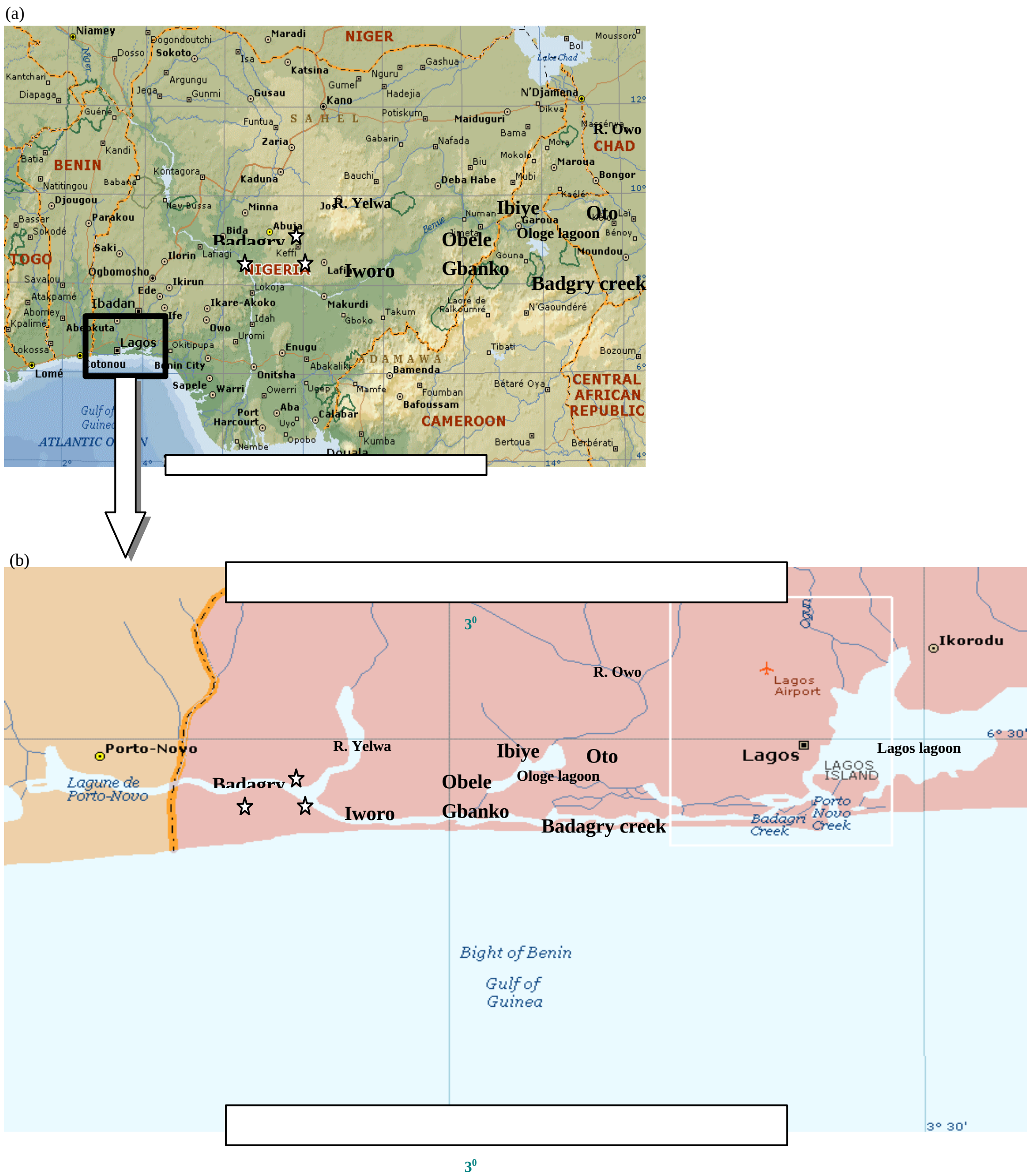

Fig. 1(a-b): (a) The administrative map of Nigeria and (b) Map of Lagos Lagoon complex showing Badagry Creek with sampling stations marked with stars

Heavy metals

Sample collection, storage and preservation: Water, sediment and fish (*C. mento*) samples were collected monthly from the four sampling stations in Badagry Creek between July, 2010 and April, 2011 for heavy metal analyses. Water samples were collected at the sampling stations at a depth of about 20 cm below water surface in 250 mL plastics bottles with screw caps. Prior to sampling, the bottles were treated by soaking them in 10% nitric acid for 24 h after which they were rinsed with distilled water (Laxen and Harrison, 1981). Immediately after sample collection, 5 mL nitric acid (AnalaR grade) was added to the water samples to reduce adsorption of metals onto the walls of the plastic bottles (APHA, 1985; Ademoroti, 1996). Sediment samples were collected using a 2 inch diameter steel pipe pressed through the water column. With this steel pipe, a sediment core of about one foot was obtained (Fishar and Ali, 2005). The sediment samples collected were placed into polythene bags. These bags have been pre-treated with 10% nitric acid. All samples were stored in a deep freezer at -10°C (Ademoroti, 1996). *Cynothrissa mento* were collected from the catches of the fishers in the four sampling stations. The fish were washed and stored in a freezer (-10°C).

Sample treatment: All frozen samples were allowed to thaw/defrost at room temperature (i.e., ~28°C). Water samples were not given any further treatment, but were mixed vigorously before aspiration into the flames of an atomic absorption spectrophotometer (Alpha-4 Cathodeon) for heavy metal determination. Values were expressed in $\mu g\ L^{-1}$.

Sediment samples were treated as follows: they were dried in an oven to constant weight at 105±20°C, ground to powder and sieved through a 2 mm mesh screen to remove coarse materials. The powdered sediment and fish samples were digested according to the methods described by American Public Health Association (APHA, 1985) and Food and Agriculture Organisation/Swedish International Development Cooperation Agency (FAO/SIDA, 1986). One gram of the sediment or fish sample was digested in a mixture containing 70% perchloric acid, concentrated nitric acid and concentrated sulphuric acid in the ratio 1:5:1. The digestion was done at temperature of 80±5°C in a fume chamber. The digestion continued until a colourless liquid was obtained. Alpha 4 cathodeon atomic absorption spectrophotometer (APHA, 1985) was used to analyse for metal concentration in each digested sediment and fish samples. The analytical procedure was checked using reference material (DORM 1, Institute of Environmental Chemistry, NRC Canada). Metal levels were expressed in $mg\ kg^{-1}$ dry weight.

Statistical analysis: Monthly variation was tested by one-way Analysis of Variance (ANOVA) (SPSS for windows version 17.0) and where there is significant variation, Fisher's least significant difference was used to separate the means. Student t-test was used to compare the two seasons (dry and wet). In all cases, the level of significance was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Physicochemical parameters: All the physicochemical parameters showed significant ($p<0.05$) monthly variation except temperature and dissolved oxygen (Table 1). However, seasonal dynamics significantly ($p<0.05$) affected 50% (6) of the physicochemical parameters (Table 2). These parameters are Total Suspended Solids (TSS), turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), alkalinity and hardness. The range of values of the water quality parameters are 0.01±0.06-4.60±0.36 ppt, 6.60±0.04-8.12±0.60, 14.00±3.06-44.00±6.56 NTU, 14.13±3.06-48.14±7.51 mg L^{-1}, 25.00±5.89-26.00±5.61°C, 41±7-122±6 mg L^{-1}, 38±4-205±17 mg L^{-1}, 48±4-344±17 mg L^{-1}; 72±6-205±11 mg L^{-1}, 88±4-202±6 and 94±15-619±20 $\mu S\ cm^{-1}$ for salinity, pH, turbidity, Biological Oxygen Demand (BOD), temperature, hardness, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), alkalinity and conductivity (Table 1). The values of some of the physicochemical parameters (turbidity, alkalinity and pH) recorded in this study are higher the values recorded in previous studies in Lagos Lagoon

Table 1: Monthly variation in physicochemical parameters of Badagry Creek

	2010				2011			
Parameter	July	August	September	October	January	February	March	April
Temperature (°C)	25.00±5.89^{a}	26.00±4.12^{a}	25.00±3.68^{a}	25.00±4.51^{a}	26.00±5.61^{a}	26.00±3.21^{a}	25.00±5.15^{a}	26.00±4.91^{a}
pH	7.10±0.46^{ab}	7.90±0.80^{a}	7.80±0.24^{a}	7.81±0.15^{a}	6.60±0.04^{bc}	7.24±0.06^{ac}	8.01±0.43^{a}	8.12±0.06^{a}
EC (µS cm^{-1})	556±26^{a}	619±20^{b}	115±16^{c}	94±15^{c}	221±17^{d}	233±19^{d}	460±23^{e}	445±29^{e}
TDS (mg L^{-1})	288±12^{a}	344±17^{b}	59±5^{c}	48±4^{c}	112±8^{d}	120±7^{d}	249±15^{ae}	233±31^{e}
Salinity (ppt)	0.30±0.06^{a}	0.34±0.09^{a}	0.10±0.06^{a}	0.10±0.06^{a}	0.10±0.06^{a}	0.10±0.06^{a}	4.60±0.36^{b}	4.00±0.32^{c}
TSS (mg L^{-1})	112±10^{a}	102±14^{a}	202±35^{bd}	168±19^{bd}	45±6^{c}	38±4^{c}	205±17^{b}	164±32^{d}
Turbidity (NTU)	38.41±3.61^{ad}	26.36±2.08^{b}	14.00±3.06^{c}	36.03±3.61^{abd}	14.43±3.06^{c}	14.81±3.05^{c}	30.13±3.21^{ab}	44.00±6.56^{d}
DO (mg L^{-1})	3.90±0.15^{a}	4.20±0.36^{a}	4.40±0.55^{a}	4.20±0.36^{a}	4.30±0.53^{a}	4.10±0.40^{a}	4.00±0.32^{a}	4.26±0.13^{a}
BOD (mg L^{-1})	48.14±7.51^{a}	28.61±3.61^{b}	38.91±3.79^{ab}	36.72±3.60^{b}	14.13±3.06^{c}	6.00±1.53^{c}	48.14±3.06^{a}	30.15±2.52^{b}
COD (mg L^{-1})	205±11^{a}	199±16^{a}	150±11^{ab}	242±15^{a}	78±9^{bc}	72±6^{bc}	198±17^{a}	138±19^{ac}
Alkalinity (mg L^{-1})	112±6^{a}	126±6^{ab}	120±7^{ac}	133±5^{bc}	88±4^{d}	112±4^{a}	130±5^{bc}	202±6^{e}
Hardness (mg L^{-1})	80±5^{a}	84±4^{a}	80±4^{a}	122±6^{b}	41±7^{c}	42±4^{c}	102±7^{d}	88±5^{ad}

Figures in the same row and with the same superscript letters are not significantly different at p>0.05, All values are Mean±SE, EC: Electrical conductivity; TDS: Total dissolved solids, TSS: Total suspended solids, DO: Dissolved oxygen, BOD: Biological oxygen demand and COD: Chemical oxygen demand

Table 2: Seasonal variation in physicochemical parameters of Badagry Creek

Parameter	Rainy season	Dry season
Temperature (°C)	24.00±1.76^{a}	25.00±1.42^{a}
pH	7.75±0.19^{a}	7.28±0.24^{a}
EC: Electrical conductivity (µS cm^{-1})	366±59^{a}	305±40^{a}
TDS: Total dissolved solids (mg L^{-1})	194±33^{a}	160±23^{a}
Salinity (ppt)	0.97±0.41^{a}	1.60±0.76^{a}
TSS: Total suspended solids (mg L^{-1})	150±12^{a}	96±27^{b}
Turbidity (NTU)	31.60±3.21^{a}	19.33±3.09^{b}
Dissolved oxygen (mg L^{-1})	4.34±0.17^{a}	4.13±0.21^{a}
BOD: Biological oxygen demand (mg L^{-1})	36.00±2.55^{a}	22.67±6.57^{b}
COD: Chemical oxygen demand (mg L^{-1})	187±15^{a}	116±30^{b}
Alkalinity (mg L^{-1})	139±9^{a}	110±6^{b}
Hardness (mg L^{-1})	91±5^{a}	62±10^{b}

Figures in the same row and with the same superscript letters are not significantly different at p>0.05, All values are Mean±SE

complex (Agboola *et al*., 2008; Ndimele, 2012). Agboola *et al*. (2008) reported turbidity (10.50±0.58-22.50±4.20 NTU), alkalinity (27.50±2.52-62.03±11.82 mg L^{-1}) and pH (7.66±0.44-7.78±0.53). However, the values of total dissolved solids (52.50±26.30-2323.50±78.20 mg L^{-1}), biological oxygen demand (159.00±42.84-243.50±63.80 mg L^{-1}) and chemical oxygen demand (368.80±36.30-1032.00±600.50 mg L^{-1}) reported by Agboola *et al*. (2008) are higher than those obtained in the present study.

The values of alkalinity (88±4-202±6) and hardness (41±7-122±6 mg L^{-1}) obtained in this study are higher than the limits recommended by Nigeria's Federal Environmental Protection Agency (FEPA, 2003). FEPA's limits for alkalinity and hardness are 20 mg L^{-1} as $CaCO_3$ and 0-75 mg L^{-1}, respectively. Most of the other physicochemical parameters fell within the limits recommended by FEPA indicating that Badagry Creek could still sustain fish and aquatic organisms.

The pH of a water body is very important because it has effect on the organisms living in the aquatic ecosystem. pH controls vital metabolic processes like respiration. Respiration is the process by which living organisms produce energy (adenosine triphosphate) required for their activities. Previous studies have recommended slightly different ranges of pH as adequate for the survival of fishes in tropical waters. Dick (1984) and Elizabeth (1990) recommended 6.5-7.5 while Huet (1972) suggested 7.0-8.0. These recommendations suggest that tropical fishes may prefer slightly alkaline environment. The pH (6.60±0.04-8.01±0.43) obtained in this study agrees with this assertion. Salinity also determines the type of organisms found in particular aquatic environments. Freshwater organisms tolerate salinity below 0.5 ppt, marine organisms thrive in salinity above 35 ppt while brackish water organisms can tolerate salinity range of 0.5-35 ppt. The salinity values (0.01±0.06-4.60±0.36 ppt) obtained in Badagry Creek in this study indicates that the water body is a brackish water environment and is in conformity with the findings of Agboola *et al*. (2008).

Turbidity is the cloudiness or haziness of a water body caused by suspended solids that are generally invisible to the naked eyes. Turbidity values less than 10 NTU represent very clear water, 50 NTU shows cloudy water and 100-500 NTU indicates very cloudy water (Barnes *et al*., 1998). High turbidity (100 NTU and above) reduces light penetration into water column which have direct negative effect on photosynthesis. Other organisms high in aquatic food chain which depend on photosynthetic plants for survival, also suffer some negative effects resulting from insufficient food. The consequences may be migration if they are motile or mass mortality and in severe cases extinction. The turbidity value (14.00±3.06-44.00±6.56 NTU) of Badagry Creek obtained in this study shows that the water body is cloudy, though the effects on the fauna may not be much. Conductivity of a water body is its ability to transmit electric current. This depends on the presence of ions in the water, that is, total dissolved solids. The highest values of conductivity (619±20 μS cm^{-1}) and total dissolved solids (344±17 mg L^{-1}) occurred in August (rainy season). This may have been due to run-offs which will dissolve any ion along its path as it flows into the Creek.

Heavy metal content of water column: The monthly concentrations of the heavy metals in water are shown in Table 3. All the six heavy metals (Cu, Zn, Cd, Pb, Fe and Cr) investigated were detected in measurable quantities in the water column of Badagry Creek and four (Cu, Zn, Pb and Fe) showed significant ($p<0.05$) monthly variation (Table 3). However, all the heavy metals did not exhibit significant ($p>0.05$) temporal (seasonal) variation (Table 4). The range of concentrations of the heavy metals recorded in the water column of Badagry Creek were Cd (2.15±0.58-3.03±0.51 μg L^{-1}), Cr (10.36±2.96-14.38±3.16 μg L^{-1}), Pb (10.48±1.56-23.38±7.16 μg L^{-1}), Cu (20.04±5.74-64.33±12.84 μg L^{-1}), Zn (17.09±6.51-103.67±23.17 μg L^{-1}) and Fe (38±10-266±73 μg L^{-1}) (Table 3). In a previous study on Badagry Creek by Agboola *et al*. (2008) cadmium, chromium and

Table 3: Monthly concentration of heavy metals in water column of Badagry Creek

Heavy metal (μg L^{-1})	2010 July	August	September	October	2011 January	February	March	April
Cu	43.33±3.33^{a}	20.04±5.78^{b}	27.43±6.51^{b}	40.67±9.67^{a}	34.33±6.74^{ab}	33.33±9.02^{ab}	31.08±9.50^{ab}	64.33±12.84^{c}
Zn	57.67±16.17^{a}	40.48±10.04^{b}	17.09±6.51^{c}	40.13±10.11^{b}	91.43±20.67^{d}	44.83±10.51^{b}	17.67±6.23^{c}	103.00±23.17^{d}
Cd	nd	3.03±0.51^{a}	nd	nd	2.67±0.88^{a}	2.42±0.58^{a}	2.86±0.73^{a}	2.15±0.58^{a}
Pb	18.32±5.84^{a}	13.33±3.33^{b}	19.46±5.51^{a}	10.48±1.56^{b}	18.33±5.84^{a}	17.36±6.51^{a}	14.14±3.06^{ab}	23.38±7.16^{c}
Fe	163.00±58.00^{a}	160.0±35.00^{a}	165.00±48.0^{a}	98.00±26.00^{b}	260.00±72.00^{c}	159.00±45.00^{a}	38.00±10.00^{d}	266.00±73.00^{c}
Cr	13.67±3.18^{a}	10.67±1.69^{a}	11.58±1.58^{a}	10.89±2.23^{a}	10.36±2.96^{a}	14.38±3.16^{a}	10.73±1.68^{a}	11.14±1.01^{a}

Figures in the same row and with the same superscript letters are not significantly different at $p>0.05$, all values are Mean±SE, nd: Not detected

Table 4: Seasonal variation of heavy metals in water, sediment and fish (*Cynothrissa mento*) from Badagry Creek

Heavy metal ($\mu g\ L^{-1}$)	Water		Sediment		*Cynothrissa mento*	
	Rain	Dry	Rain	Dry	Rain	Dry
Cu	39.07±19.31[a]	32.89±13.18[a]	0.23±0.06[a]	0.19±0.04[a]	0.49±0.06[a]	0.16±0.05[b]
Zn	51.67±19.54[a]	50.89±16.98[a]	0.66±0.13[a]	0.84±0.17[a]	1.16±0.46[a]	0.69±0.06[b]
Cd	11.80±3.09[a]	10.89±1.17[a]	0.39±0.18[a]	0.38±0.12[a]	0.02±0.01[a]	0.01±0.01[a]
Pb	16.80±6.48[a]	16.44±4.25[a]	0.65±0.17[a]	0.68±0.15[a]	0.03±0.01[a]	0.01±0.01[a]
Fe	169.00±50.00[a]	153.00±49.00[a]	571.00±58.00[a]	62.00±11.00[b]	11.35±1.69[a]	8.52±1.42[a]
Cr	11.41±2.59[a]	11.89±3.22[a]	0.02±0.01[a]	0.01±0.01[a]	0.01±0.01[a]	0.03±0.01[a]

Figures in the same row and with the same superscript letters are not significantly different at $p>0.05$, All values are expressed as Mean±SE

lead were not detected in the water column. The detection of these three heavy metals in the present study shows that their levels in the water column of Badagry Creek have increased. This increase may have been caused by natural processes like weathering particularly for chromium. Anthropogenic factors such as discharge of industrial effluent are not a likely cause of the increase because there are no industries around the Badagry Creek. The increase in lead (Pb) level may be as a result of increase in vehicular traffic. Lead tetraethyl is used as anti-knock in the refining of petroleum for automobile use. The Pb becomes available to the atmosphere and even water bodies when the petrol is used to power automobile like cars (Ndimele *et al*., 2009).

The concentrations of some of the heavy metals in water column of Badagry Creek recorded in this study agree with earlier studies carried out in this water body and other water bodies in Nigeria. Agboola *et al*. (2008) reported annual Fe concentration of 0.22±0.08-1.01±0.79 mg L^{-1} in Badagry Creek while Obasohan and Eguavoen (2008) reported Cu (1.0-63 $\mu g\ L^{-1}$) and Zn (1.0-110 $\mu g\ L^{-1}$) in Ogba River, Benin City, Nigeria. The concentrations of Cu recorded in this study are higher than the values reported in two previous studies in Ologe Lagoon (Badagry Creek empties into Ologe Lagoon) by Ndimele *et al*. (2011a) and Kumolu-Johnson *et al*. (2010). Ndimele *et al*. (2011b) obtained mean annual Cu values of 4.25±0.12 $\mu g\ L^{-1}$. However, there was reduction in Zn level when compared to the value (862±38 $\mu g\ L^{-1}$) reported by Kumolu-Johnson *et al*. (2010) in Ologe Lagoon, Lagos, Nigeria. These inconsistencies or fluctuation in the concentrations of heavy metals in the water column of an aquatic ecosystem like Badagry Creek may have been caused by the complex interactions between different compartments of the ecosystem (Kumolu-Johnson *et al*., 2010). Sediment size, partition coefficient (Kd), cation exchange, organic matter content and mineral constituents are some of the factors that influence the uptake of heavy metals in the aquatic environment. The decrease in Zn level may be as a result of the presence of water hyacinth (*Eichhornia crassipes*) in Badagry Creek. Water hyacinth have been reported to have the ability to remove pollutants like heavy metals from water (Ndimele, 2010; Ndimele and Jimoh, 2011; Ndimele *et al*., 2011b).

The concentrations of the heavy metals recorded in the water column of Badagry Creek in the present study fall within the limit recommended by World Health Organisation for drinking water (WHO, 2008). World Health Organisation recommendations are Cu (2000 $\mu g\ L^{-1}$), Zn (3000 $\mu g\ L^{-1}$), Fe (2000 $\mu g\ L^{-1}$), Cd (3 $\mu g\ L^{-1}$), Pb (10 $\mu g\ L^{-1}$) and Cr (50 $\mu g\ L^{-1}$). However, Cu (20.04±5.74-64.33±12.84 $\mu g\ L^{-1}$) and Zn (17.09±6.51-103.67±23.17 $\mu g\ L^{-1}$) values in this study are higher than the limits (Cu, 4.70 $\mu g\ L^{-1}$ for a 4 day average at 45 mg L^{-1} hardness; Zn, 6 $\mu g\ L^{-1}$ at 45 mg L^{-1} hardness) for the protection of aquatic ecosystems (USEPA, 1996).

Table 5: Monthly concentration of heavy metals in sediment of Badagry Creek

Heavy metal (mg kg^{-1})	2010				2011			
	July	August	September	October	January	February	March	April
Cu	0.22 ± 0.02^{a}	0.29 ± 0.01^{a}	0.14 ± 0.01^{a}	0.11 ± 0.01^{a}	0.18 ± 0.02^{a}	0.20 ± 0.02^{a}	0.18 ± 0.02^{a}	0.41 ± 0.03^{a}
Zn	0.75 ± 0.15^{ab}	0.26 ± 0.07^{a}	0.60 ± 0.15^{ab}	0.66 ± 0.27^{ab}	1.24 ± 0.34^{b}	0.85 ± 0.16^{ab}	0.44 ± 0.17^{a}	1.04 ± 0.32^{b}
Cd	0.49 ± 0.15^{b}	0.09 ± 0.03^{a}	0.84 ± 0.19^{c}	0.15 ± 0.06^{a}	0.44 ± 0.15^{b}	0.22 ± 0.06^{a}	0.49 ± 0.09^{b}	0.38 ± 0.10^{b}
Pb	0.48 ± 0.11^{a}	0.18 ± 0.04^{c}	0.84 ± 0.21^{ab}	0.60 ± 0.15^{ad}	0.62 ± 0.13^{ad}	1.12 ± 0.12^{b}	0.31 ± 0.08^{a}	1.14 ± 0.61^{b}
Fe	296.00 ± 53.00^{a}	154.00 ± 39.00^{b}	20.00 ± 3.00^{cd}	17.00 ± 2.00^{e}	144.00 ± 18.00^{b}	30.00 ± 5.00^{d}	12.00 ± 2.00^{c}	62.00 ± 6.00^{e}
Cr	0.02 ± 0.01^{a}	0.03 ± 0.01^{a}	0.01 ± 0.01^{a}	0.01 ± 0.01^{a}	0.03 ± 0.01^{a}	0.01 ± 0.01^{a}	0.04 ± 0.01^{a}	0.06 ± 0.01^{a}

Figures in the same row and with the same superscript letters are not significantly different at $p>0.05$, All values are Mean±SE

Heavy metal content of sediment: Comparison of heavy metal content in sediments in different aquatic ecosystems may be a convenient way of assessing the pollution status of an environment. However, this method has its limitations. Sediment metal concentrations are influenced by a range of factors. They include physical and hydrological characteristics of the region and its benthic population, atmospheric conditions, productivity, pH, soil texture, redox potential and cation exchange capacity among others. Inspite of the shortcomings of sediment as an indicator of pollution, it still remains an important component of the aquatic ecosystem because it acts as reservoir for heavy metals. Therefore, the internal geochemical processes that could result in the remobilization of pollutants should be taken into consideration (Belzile *et al.*, 2004).

The range of concentration of heavy metal in sediment of Badagry Creek are Cr (0.01±0.01-0.06±0.02 mg kg^{-1}), Cd (0.09±0.03-0.84±0.19 mg kg^{-1}), Cu (0.11±0.01-0.41±0.03 mg kg^{-1}), Pb (0.18±0.04-1.14±0.61 mg kg^{-1}), Zn (0.26±0.07-1.24±0.34 mg kg^{-1}) and Fe (17±2-296±53 mg kg^{-1}) (Table 5). All the heavy metals had significant ($p<0.05$) monthly variations except Cr. However, only Fe was significantly ($p<0.05$) affected by seasonal dynamics (Table 4). The concentrations of heavy metals in sediment of Badagry Creek have similar values to the ones obtained by Ndimele *et al.* (2011a) in their study of the metal contents of Ologe Lagoon. They reported Cu (0.55±0.05-1.25±0.09) and Fe (100.58±12.69-313.74±35.79) while Ndimele *et al.* (2009) reported Pb concentration of 0.05±0.01-4.12±1.25 mg kg^{-1} in Ologe Lagoon, Lagos, Nigeria. The values are below the limits set by World Health Organisation (WHO) and United States Environmental Protection Agency (USEPA) except Fe. WHO (2008) recommended Cu (25 mg kg^{-1}), Zn (123 mg kg^{-1}) and Cd (6 mg kg^{-1}) while USEPA (1996) recommended Fe (30 mg kg^{-1}), Pb (40 mg kg^{-1}) and Cr (25 mg kg^{-1}). The high Fe level observed in the sediments of Badagry Creek has been reported in earlier studies by Kakulu and Osibanjo (1988) and Kumolu-Johnson *et al.* (2010). Asaolu and Olaofe (2005) made a similar observation and reported that the concentrations of Fe in Nigerian soils and most soils all over the world are naturally high.

Heavy metal content of *Cynothrissa mento*: The concentrations of heavy metals recorded in *C. mento* from Badagry Creek exhibited significant ($p<0.05$) monthly variation except Cd and Cr (Table 6). However, only Cu and Zn were significantly ($p<0.05$) influenced by seasonal variation (Table 4). The range of heavy metals in *Cynothrissa mento* recorded in this study are 0.01±0.01-0.05±0.02 mg kg^{-1}, 0.01±0.01-0.05±0.02 mg kg^{-1}; 0.01±0.01-0.12±0.01 mg kg^{-1}, 0.06±0.02-0.91±0.19 mg kg^{-1}, 0.19±0.04-1.69±0.33 mg kg^{-1} and 4.33±0.43-16.88±1.32 mg kg^{-1} and for Cr, Cd, Pb, Cu, Zn and Fe respectively (Table 6). These values are lower than the concentrations (Cu: 1.19±0.23-1.57±0.26 mg kg^{-1}, Zn: 20.60±5.20-38.50±2.80 mg kg^{-1}, Fe:

Table 6: Monthly concentration of heavy metals in *Cynothrissa mento* from Badagry Creek

Heavy metal (mg kg^{-1})	2010				2011			
	July	August	September	October	January	February	March	April
Cu	0.61 ± 0.06^{ac}	0.14 ± 0.03^{ab}	0.41 ± 0.05^{a}	0.91 ± 0.19^{c}	0.34 ± 0.09^{a}	0.06 ± 0.02^{b}	0.07 ± 0.02^{b}	0.38 ± 0.08^{a}
Zn	0.81 ± 0.04^{ad}	0.66 ± 0.07^{a}	1.19 ± 0.04^{ac}	1.46 ± 0.12^{cd}	0.66 ± 0.08^{a}	0.19 ± 0.04^{e}	1.22 ± 0.24^{ac}	1.69 ± 0.33^{bc}
Cd	0.01 ± 0.01^{a}	0.02 ± 0.01^{a}	0.04 ± 0.01^{a}	0.01 ± 0.01^{a}	0.03 ± 0.01^{a}	0.05 ± 0.02^{a}	0.04 ± 0.01^{a}	0.03 ± 0.01^{a}
Pb	0.12 ± 0.01^{a}	0.01 ± 0.01^{b}	0.02 ± 0.01^{b}	0.03 ± 0.01^{b}	0.02 ± 0.01^{b}	0.03 ± 0.01^{b}	0.02 ± 0.01^{b}	0.04 ± 0.01^{b}
Fe	16.88 ± 1.32^{a}	4.33 ± 0.43^{b}	10.21 ± 1.08^{cd}	14.21 ± 1.70^{ac}	11.92 ± 0.98^{c}	8.55 ± 0.83^{bd}	5.08 ± 0.75^{b}	11.13 ± 1.80^{c}
Cr	0.01 ± 0.01^{a}	0.03 ± 0.01^{a}	0.04 ± 0.02^{a}	0.05 ± 0.02^{a}	0.03 ± 0.01^{a}	0.05 ± 0.02^{a}	0.04 ± 0.02^{a}	0.05 ± 0.02^{a}

Figures in the same row and with the same superscript letters are not significantly different at $p>0.05$, All values are Mean±SE

31.80±4.20-43.20±7.60 mg kg^{-1}) obtained by Kumolu-Johnson *et al.* (2010) in *C. mento* from Ologe Lagoon, Lagos, Nigeria. This might be due to the discharge of industrial effluent into Ologe Lagoon by industries operating in Agbara Industrial Estate which is located near Ologe Lagoon. There are no industries near Badagry Creek which can discharge industrial effluent into the creek. The major form of pollutant is domestic waste from the riverine population.

The heavy metal contents of *C. mento* observed in this study is lower than the values reported in previous studies. Oguzie (2009) reported Cu (2.50±0.05 mg kg^{-1}), Zn (2.80±0.05 mg kg^{-1}), Cd (0.72±0.02 mg kg^{-1}), Pb (1.60±0.03 mg kg^{-1}) and Cr (1.80±0.05 mg kg^{-1}) in *Parachanna obscura* from Ikpoba River, Benin City, Nigeria. Obasohan *et al.* (2006) obtained Cu value of 4.17-6.46 mg kg^{-1} in *Malapterurus electricus* and *Chrysichthys nigrodigitatus* from Ogba River, Benin City, Nigeria. The low level of Cd and Cr in *C. mento* from Badagry Creek is not surprising because of the absence of industries in Badagry which can discharge effluents into the creek. The high level of Zn and Fe in fishes from Nigerian water has also been reported in previous studies (Kakulu and Osibanjo, 1988; Asaolu and Olaofe, 2005; Ndimele *et al.*, 2011a). This may have been caused by the natural occurrence of these metals in high concentrations in Nigerian soils. The soil also act as sink for these metals and the internal geochemistry of ecosystems can remobilize the heavy metals into the water column where they can be absorbed by fishes. The concentrations of heavy metals in *C. mento* recorded in this study were within the limits recommended in fish and fishery products by the Food and Agriculture Organisation (FAO) of The United Nations Organisation (Nauen, 1983).

CONCLUSION

This study has shown that the physicochemical parameters of Badagry Creek can adequately sustain aquatic fauna especially fishes. It has also been shown that the heavy metal contents of water, sediment and *Cynothrissa mento* from Badagry Creek are within the recommended limits.

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